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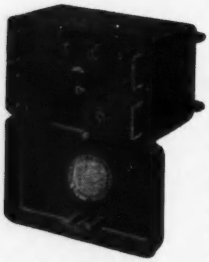

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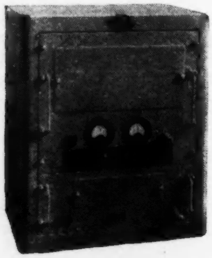

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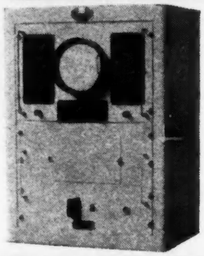

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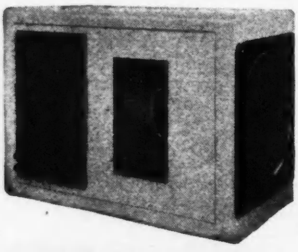

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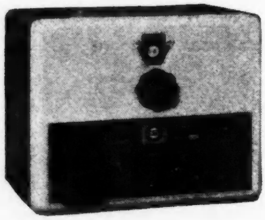

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THE MAGAZINE OF SCIENTIFIC PROGRESS

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The Progress of Science

Electronics in Industry

WORKING ten per cent harder may help temporarily to solve our export problem. But it will help only so long as the present world-wide seller's market lasts. After that we shall be in direct competition with exports from countries which produce more cheaply than we do. To hold our own then the prices of our goods will have to be reduced, and the most important contribution to this price reduction can only come from the reducing of production costs. Unless we can materially reduce our production costs, it will be of little use to produce ten per cent more, for we shall not be able to sell what we make.

Ultimately the decisive factor in production costs is the number of man-hours of labour that have to be used up in order to make the article concerned; wage levels do have some effect, of course, on the cost, but in the long run it is a small one compared with the effect of economy in the use of labour. The number of man-hours required to turn out a particular article depends largely on a degree to which automatic production is used. If machines are automatic then one worker can attend to the maintenance of many of them so that his labour is used to the maximum effect. The essential reason why America in particular can sell so many things cheaper than we can is that automatic methods are used more extensively there. These methods have boosted the average productivity of American labour, which today is at least two-and-a-half times as great as our own.

Almost all automatic processes require the intervention of some sort of control to correct small cumulative errors and ensure that the machine continues to do the correct operation instead of gradually deviating from it. Until a decade or two ago, the control mechanism was invariably a human being, who watched for the deviations and applied appropriate corrections. In most cases this human being was not used for any of his more specifically human properties—his thinking power or judgment. He was really no more than a sort of servo-mechanism, to use a term that is becoming fashionable, involving a delicate detector—such as the eye—and a motor—such as the arm muscle—which gave an appropriate response. But electronic devices present exactly the same characteristics. They can detect with even greater delicacy than any human sense; only an inappreciable force need be used to put them in action; but through amplification they can give in response an output as large as may be desired to correct the running of the machine. If great accuracy is required, they can beat the human servo-mechanism hands down. They can work at much higher speeds. And, to quote Furnas, they "never get sleepy, no matter how late they may have been up the night before".

In the last two decades there has been a very rapid development in electronically-controlled automatic machines. But—in spite of welcome exceptions like the automatic radio factory (Fig. 2) which we described in some detail last year (Vol. 8, pp. 99–100)—the development has been largely an American one. The Americans have published consistently about twice as much material on the subject as we have, while there are at least three monthly periodicals in the U.S.A. devoted entirely to electronics in industry. It would be more difficult to obtain statistics of the use of these methods; almost certainly the bias would be even more strongly American, and that is a very large part of the explanation of the lower American costs. It is significant that a list of American firms making such electronic equipment runs into several hundreds.

There are very few mass production processes to which electronic control cannot be advantageously applied. The photo-cell is the detector in the majority of them (perhaps only because the human eye was the earlier detector and we merely use the most convenient substitute), but many other methods have also proved useful.

The Bessemer process of steel making can be automatically controlled by photo-cells which observe the colour of the flame, and furnace temperatures may be regulated by a similar device. In rolling mills the thickness of the product may be used to control the speeds of the different rollers so as to avoid slack or stretch. Lathes and milling machines can be fitted with photo-cell devices that will follow a template and actuate the machine so as to cut the work to the same shape.

In the inspection of engineering products—a process in which the human element is most liable to failure

from fatigue or boredom—electronic methods are almost universally applicable. Gauges can be used which will automatically throw out any faulty parts. Fine holes can be inspected to ensure that they are not blocked by waste. Flaws and cracks in metals can be detected by the variations they produce in supersonic or high-frequency electro-magnetic fields. Surface finish can be checked by an instrument which magnifies to appreciable proportions the tiny movements of a stilus passing over the surface. Unevenness can be detected in high-grade paper or in enamel coatings on metals, using an optical system and a photo-cell. Pin holes in the enamel insulation of copper wire can be rapidly discovered by passing it through a mercury bath and counting electrically the number of times a current leaks from the wire to the bath. Metal particles in foodstuffs can be detected by their effect on a radio-frequency field.

In many milling and crushing operations—of ore, rock, grain, sugar, etc.—'tramp metal' such as iron bolts and nails may get into the hopper, and if they do the mill may be wrecked, or at least the rollers scored. There is a wide field for detecting such foreign bodies and dropping the material containing them out of the conveyor so as not to cause damage. This represents an industrial application of the war-time 'mine detector'.

In colour printing the photo-cell can be used to ensure

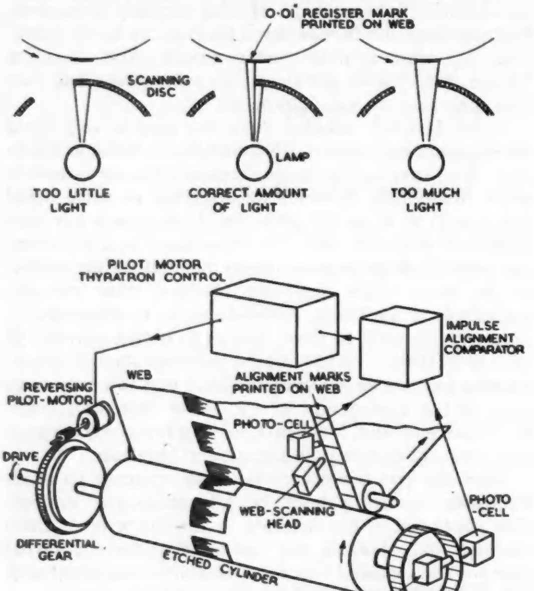

FIG. 1.—A photo-electric control to ensure accurate register between the successive impressions in colour printing on a rotary press. Alignment marks are printed on the edge of the roll of paper, and there is a corresponding set of marks on the scanning disc attached to the cylinder. Two photo-cells continuously compare the positions of the two sets of marks. When they get out of step a thyratron control actuates a reversing electric motor which operates the differential gear to adjust the position of the roller. (*Reproduced from the Journal of the Institution of Electrical Engineers.*)

an accurate register between the several impressions. This is particularly important in colour printing on rotary presses (see Fig. 1).

Our textile industry has much to gain from the application of electronic techniques. They can be used for automatic squaring-up of cloth that has gone askew, i.e. in which the warp and weft thread are not at right-angles. They can continually watch the strength and uniformity of the yarn in spinning and make appropriate adjustments. They can take complete charge of colour matching.

These are but a few of the ways in which electronic controls can boost industrial efficiency. Naturally the question occurs: what of the capital cost? Will this outweigh the savings in production? And in any case, considering the situation of Britain now, is the capital effort too great to be carried out before it is too late? Obviously it would be best in the long run to design whole machines and even whole factories to make the optimum use of electronic methods. But more short-term tactics are possible. In many cases it would be feasible to keep the present machine and merely to add an electronic controlling device which will take the place of the human being who has hitherto been responsible for control. In that case the saving of labour costs will still be great, but the capital cost will be that of the controlling device alone. And, quoting Dr. H. A. Thomas, of the National Physical Laboratory, who is actively agitating for a greatly increased use of electronic controls, "The quantity of electronic equipment needed is small, the cost is negligible in comparison with the improved output which can be obtained, and there are available many electronically minded technicians capable of developing such equipment."

Dr. Thomas has written two most useful articles on the subject, which have been published in the *Board of Trade Journal* (July 26, 1947) and *Journal of the Institution of Electrical Engineers* (1947, Vol. 94, Part I, pp. 309–38). In the latter paper he suggested that "there is need for a publicity campaign to make industry fully aware of the potentialities of electronic applications, and that such a campaign could with great advantage to many industries in the country be sponsored by a new organisation devoted entirely to the exploration of possible fields of application." We welcome these suggestions. Full awareness of the great possibilities that are within reach is a pre-requisite to widespread application of automatic control devices. We hope that Dr. Thomas's suggestion for a development organisation will come into effect and that this will be established on a scale sufficiently ambitious to produce effective results quickly.

READING LIST

In addition to the two papers quoted above, readers will find several useful contributions on this subject published in the *Journal of the Institution of Electrical Engineers* during 1947. The following books deal with the subject:

Industrial Electronics, by Gulliksen and Vedder, (Wiley, N. York).

Fundamentals of Industrial Electronic Circuits, by Walther Richter (McGraw Hill, N. York).

Engineering Electronics, by Donald G. Fink (McGraw Hill).

Electronic Equipment and Accessories, by R. C. Walker (Newnes, London).

Electronics and their Application in Industry and Research, (Pilot Press, London).

FIG. 2.—This robot machine makes complete radio sets at the rate of one every 20 seconds. Known as E.C.M.E. (Electronic Circuit-making Equipment), it is built in two batteries each 70 feet long. Each battery is a series of fully automatic machines governed by electronic control devices. Each battery builds, upon preformed plastic plates, all the necessary inductances, capacitors, resistors, and other components necessary to make a radio receiver. On leaving the batteries the plates are complete, and the only handwork necessary is the fitting of valves, electrolytic condensers and loud-speaker. In short, the E.C.M.E. needs only two workers to feed the plates into it, after which it carries out all the complicated operations which a highly skilled and organised double line of workers would normally carry out. Owing to the basic principle of spraying the circuits on to the pre-formed plates, wiring mistakes cannot happen. A series of automatic tests during processing cuts out inspection-costs. In the event of any failure, the electronic controls will cut out a whole series of operations and report the precise position of the defect. (*COI photograph.*)

An Invasion by Barnacles

WHEN the presence in Chichester Harbour of the Australian barnacle *Elminius modestus** was first reported about a year ago it had little more than academic interest, comparable with that aroused by the appearance of the continental fresh-water shrimp *Orchestia cavimana* in the Thames in 1942. Such introductions of foreign species of invertebrate are not rare, but this was a rather unusual example: not only is the species of barnacle confined to the coasts of Australia and New Zealand; but the genus *Elminius*, with the exception of a single record from the Azores, is unknown from outside the Southern Hemisphere.

No one expected it to cause any more inconvenience than the common British barnacles which it closely resembles in appearance and habits. Many species of barnacle are a nuisance because they foul the bottoms of ships, and in this respect experience has proved that *Elminius* is no worse than any other. It now appears, however, that the Australian barnacle is going to be a pest (though scarcely so serious a one as the rabbits and thistles which were introduced into Australia from Britain), for it is spreading rapidly round the coast and threatens to interfere with our shell-fish industry.

During the past year *Elminius* has been found in suitable estuaries all along the south coast and has become the dominant organism in the lower reaches of the Colne, Crouch, Blackwater and Thames. Its spread appears to have been very rapid. This impression is supported by the fact that there is a dense population on the piers and landing stages of places like Whitstable, while the equally crowded communities on the shores around are of small, young individuals, which are evidently their immediate descendants.

It is rather surprising that a barnacle which is proving itself so well suited to the climatic and other conditions of our estuaries should not have established itself before. *Balanus tintinnabulum* and *Balanus amphitrite* are common on the bottoms of ships from tropical ports. These barnacles remain healthy and active for long periods after their arrival in British waters, but usually do not breed in our waters which are too cold. That these species would do so if our climate were congenial is indicated by the discovery in the artificially heated water of Shoreham Harbour in 1937 of a colony of *B. amphitrite* (together with a tube-building worm foreign to our shores). It is not that *Elminius* does not get carried on ships—it has even been found alive on the hull of a ship from Australian ports which came to this country via the Panama Canal, and no doubt it is transport by shipping which is responsible for its rapid spread around our coast. But it does not seem to survive long journeys readily.

It is interesting to note that the earlier pest of British oyster beds, the slipper limpet (*Crepidula fornicata*),

* A photograph of this barnacle will be found on p. 124 of this issue.

introduced with American oysters, took about 50 years to achieve the same distribution as *Elminius*.

Like the slipper limpet, barnacles are a nuisance to the shell-fish industry in more ways than one. They settle on the shells of winkles, mussels and oysters, and lower their commercial value. In the past shell-fish from muddy estuaries have been comparatively free from barnacles in this country. The barnacle most successful in British estuaries is *Balanus improvisus*, but this species is unable to grow well if the water is too muddy; as a result winkles from the mud flats of the Blackwater and similar places have hitherto always been very clean and free from barnacles. *Elminius modestus* is adapted for life in temperate Australian estuaries and seems to be able to withstand the muddy water of our estuaries better than any of our native barnacles. Already there have been complaints about barnacles on winkles from sources from which the trade is accustomed to receive clean winkles, and investigation has shown that *Elminius* is mainly responsible for the trouble.

Oysters are scraped clean of any barnacles before they are put on the market, so that the labour so used is likely to increase if the threatened invasion of our oyster beds by *Elminius* materialises. It is, however, as a competitor for the food and living space of the oysters that this barnacle is likely to prove most troublesome. Although barnacles are crustaceans and oysters are molluscs, they both have very similar life histories. The adults of both are sedentary and depend for the dispersal of the species on starting life as free-swimming larvae which, after being carried by the currents from one locality to another, reach a stage in their development when they settle on any convenient rock or other hard substratum. The species which settles first does not thereby gain any advantage; on the contrary it runs the greater risk of being sat on, for neither the oyster nor the barnacle has any means of preventing the larvae of the other from settling on its own hard shell. Oyster spat settles late, two or three months later than the larvae of British barnacles which settle in the spring; and the young oysters are usually able to grow over and smother the barnacles. The oyster takes several years to grow, however, and it sometimes happens that the barnacles settling the following spring do so in such large numbers that they grow into a continuous layer over the young oysters and kill them. *Elminius*, unfortunately, continues to settle throughout the summer months and so will have much more opportunity than native barnacles of overgrowing young oysters.

The Sting of a Nettle

THE course of events that ensue when one makes contact with the stinging hairs of a nettle was something of a mystery until quite recently. That it is the hairs covering the nettle leaves and stems which cause the sting has, of course, been known for a long time. In the smaller species of nettle (*Urtica urens*), which grows about a foot high, all the hairs are stinging hairs. The common nettle (*Urtica dioica*) has ordinary hairs in addition to the stinging hairs.

A stinging hair is constructed on the following plan. The hair tapers and ends in a small head, and as the wall of the hair is silicified at the end and calcified below, it is extremely stiff. The head breaks off at the slightest touch, leaving a sharp point which pierces the skin and allows the hair fluid to enter. The hairs are inclined forward, so that, if a nettle leaf is pressed, especially from a backwards direction, the hairs are crushed flat and no stinging results.

The mechanism of the sting is now more clearly understood with the publication of the results of an investigation made by two research workers at Cambridge University, Dr. N. Emmelin and Dr. W. Feldberg. They were able to show the presence in the stinging hairs of at least three pharmacologically active substances. Two of these are histamine and acetylcholine. The third substance still awaits identification.

A solution of histamine and acetylcholine would cause effects almost identical with those due to a nettle sting if a drop of the liquid were injected into the skin.

Histamine and acetylcholine are both extremely active in very small amounts and widely distributed, and have important functions in the living organism. Both have powerful effects on muscle fibres and this property is utilised for their detection and estimation (Fig. 3). A piece of muscular tissue from a freshly killed animal, such as a short length of guinea-pig intestine or a frog muscle, is suspended in a suitable fluid and maintained under slight tension while attached to one end of a lever whose other end can make a trace on a slowly revolving smoked drum. Addition of a drug such as histamine to the fluid surrounding the muscle preparation causes a contraction which is recorded on the drum. The presence of certain active compounds in a fluid can be detected and the amount present measured, even though it may be very minute, by studying the response of different tissues and the effects of adding drugs known to accentuate or inhibit the action of the specific active substance sought. Using this type of pharmacological test the Cambridge

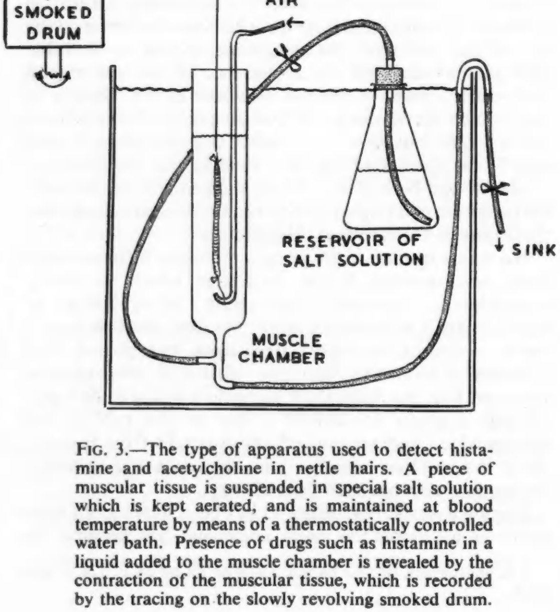

FIG. 3.—The type of apparatus used to detect histamine and acetylcholine in nettle hairs. A piece of muscular tissue is suspended in special salt solution which is kept aerated, and is maintained at blood temperature by means of a thermostatically controlled water bath. Presence of drugs such as histamine in a liquid added to the muscle chamber is revealed by the contraction of the muscular tissue, which is recorded by the tracing on the slowly revolving smoked drum.

workers were able to detect the presence of histamine and acetylcholine in the stinging hairs of nettles. When substances that inhibited both these active compounds were added, the sting fluid still caused some contraction of an isolated piece of guinea-pig intestine, so that the presence of a third active but unidentified substance had to be postulated.

Histamine is a substance closely related chemically to the amino-acid histidine (one of the units from which proteins are built) and is probably formed from it in the tissues. Few other drugs have so wide a variety of actions as histamine. Almost all tissues will respond in some way to it. The injection of a thousandth of a milligram into man will dilate his veins and small arteries and produce a sharp fall in blood pressure. A larger dose will cause a copious flow of acid gastric juice in the stomach. (Some physiologists believe that histamine is identical with the hormone, *gastrin*, which is liberated into the bloodstream when food enters the stomach and causes an increased flow of digestive juice.)

An intense mechanical stimulation of the skin, as for example by the lash of a whip, produces effects usually described as the *Triple response*. First of all, a *red reaction* appears at the site of injury due to the dilation of the skin capillaries, next a *red flare* is produced as a bright red flush spreads out from the original red area, and finally the central area grows paler and the skin becomes raised up above its surroundings as a *wheal* develops. These effects are believed to be produced by the liberation of some material at the site of injury, now generally believed to be histamine itself. An identical triple response can be produced experimentally by pricking a solution of histamine into the skin. The triple response will be recognised as the familiar effect produced by the nettle sting and is due to the histamine injected from the hair into the skin. The hair fluid contains 0·1–0·2% of histamine. About a thousand million hairs contain an ounce of histamine.

The additional burning sensation produced by a nettle sting is caused by the acetylcholine simultaneously present.

A large number of the organs of the body, such as the heart, blood vessels, iris, intestines and many others are controlled by the involuntary nervous system which functions automatically without our being conscious of it. The nerve impulses reaching an organ do not stimulate it directly but release chemical substances at the nerve endings to which the organ tissues are very sensitive. One of these substances which acts as a vital link between the nerve impulse and the organ to be controlled has been identified as acetylcholine. Only very small amounts indeed of it are liberated at nerve endings, but this is compensated for by the extremely high sensitivity of tissues towards it. A leech muscle, for instance, will react to a solution containing one part of acetylcholine in 2,000,000,000! A single nettle hair was shown to contain sufficient acetylcholine to cause an isolated frog muscle to contract, while an extract of ten hairs would cause a fall in blood pressure when injected into cat or rabbit. Using these and other methods, it was found that the hair fluid contained about 1% of acetylcholine, a surprisingly high concentration to find in a biological fluid.

REFERENCE

N. Emmelin and W. Feldberg, *Journal of Physiology*, 1947, **106**, 440.

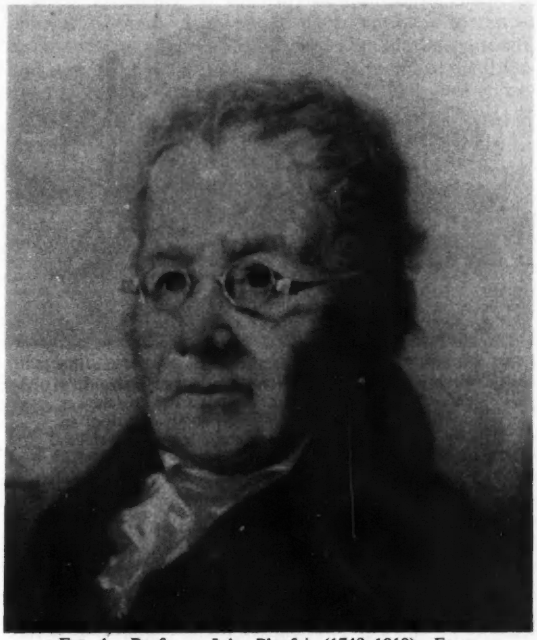

FIG. 4.—Professor John Playfair (1748–1819). From a sepia drawing by W. Nicholson in the Scottish National Portrait Gallery. (*Reproduced by permission of the Trustees.*)

John Playfair (1748-1819)

THE progress of science requires not only its discoverers but also its fighters. It is not enough to find out the truth; the world must also be convinced. And sometimes a man whose original contributions to scientific knowledge are small deserves our thanks and remembrance for his struggles to propagate scientific ideas which were being held back by the prejudices, inertias and resistances of his age. A case in point is John Playfair, who was born in Benvie, near Dundee, on March 10, 1748.

Playfair did make significant contributions to knowledge. He was, for instance, the first to realise at all clearly the geological role of glaciers, and he produced several mathematical and physical works of merit but not of genius. It may be that mere lack of opportunity prevented him from doing more. He showed signs of brilliance in youth, but was frustrated by the fact that he could not find any position giving full opportunity for scientific work, until in 1785 he was appointed Professor of Mathematics at Edinburgh. He was then thirty-seven years old—by which age most scientists have done their best original work. Even so, his main original work was done after that date: yet we can well believe that it was his age which caused him to concentrate rather on fights against prejudice.

In last December's 'Progress of Science' we wrote of James Hutton and how the prejudices of his age prevented the acceptance of his essentially modern geological theory. Playfair was one of the small band whom Hutton convinced, and after the latter's death in 1797 Playfair made it one of his main objectives to struggle for the acceptance

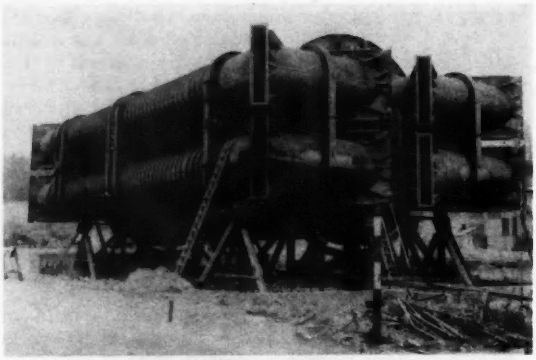

FIG. 5.—This stratosphere chamber erected at the Weybridge factory of Vickers-Armstrong is the world's largest. A vacuum pump driven by a 140-horsepower motor will reduce the chamber to one-twentieth of an atmosphere pressure in 90 minutes—in the early stages of evacuation the rate corresponds to a climb of a thousand feet per minute. The chamber is 25 ft. in diameter, 50 ft. long, and 40,000 cu. ft. in volume. It weighs 215 tons. It can be cooled to below —70°C. After a heat-insulating cover has been added, the whole will be enclosed by a steel-framed shed. (*COI photograph.*)

of the Huttonian theory. Realising that Hutton's obscure style was one of the reasons for the contemporary failure to appreciate the theory—at least it explained why his contemporaries could so easily distort it before proceeding to demolish their men of straw—he wrote a beautifully clear account of the theory in his *Illustrations of the Huttonian Theory of the Earth* (1802). Even here he added much fresh evidence and important new ideas. But that was not enough for him; he planned to publish a much improved second edition, which was unfortunately uncompleted at the time of his death. To prepare the material he travelled widely in the British Isles. The Napoleonic wars prevented him from going farther afield till 1815, but it is typical of the man that the peace of that year meant to him simply the long wished-for opportunity to extend his observations to France and Switzerland. The rather meagre notes he left are sufficient to make it the investigation that the real nature of scientific work and method can be learnt.

Playfair did not live to witness the success of his geological fight. But another of his struggles brought more immediate results. This was a time when British mathematics was in an extremely decadent state. On the Continent, the past century had been marked by brilliant progress, culminating in Laplace's *Mécanique Céleste*; but in this country mathematics had made scarcely any progress since Newton. Playfair was one of the very few in his day who tried to bring British mathematics into line with the continental.

Typical of his more polemical efforts was his 36-page review of Laplace's book in the *Edinburgh Review* for January 1808. The last five pages of this most carefully thought-out critique were devoted to the state of British mathematics. "In the list of mathematicians and philosophers," he begins, "to whom that science, for the last sixty or seventy years, has been indebted for its improvement, hardly a name from Great Britain falls to be mentioned." He reckons that not more than a dozen people in his country would have the equipment to read Laplace. As contributory to this decadence he mentioned certain historical causes, but he finds the chief cause in the backwardness of Oxford and Cambridge Universities. "In one of these, where the dictates of Aristotle are still listened to as infallible decrees, and where the infancy of science is mistaken for its maturity, the mathematical sciences have never flourished; and the scholar has no means of advancing beyond the mere elements of geometry." In the other, mathematics is the main study, but the methods are very bad. "A certain portion of the works of Newton, or of some other of the writers who treat of pure or mixt mathematics in the synthetic methods, is perscribed to the pupil, which the candidate for academical honours must study day and night . . . not to learn the spirit of geometry . . . but to know [the theorems] as a child does his chatechism, by heart, so as to answer readily to certain interrogations. In all this, the invention finds no exercise; the student is confined within narrow limits; his curiosity is not roused; the spirit of discovery is not awakened."

As might be expected, the first reaction was one of outraged indignation. The anonymous author of the preface to a volume of Cambridge Examination papers, published in 1810, waxes exceeding wrath at Playfair, and claims that the questions in the collection demonstrate that the student is required to exercise invention. But a glance at these questions proves Playfair right—they range from simple interest to questions in the calculus which at the best date from sixty years earlier. But the attack on this obsolete teaching was gaining support daily, and Playfair lived to witness a complete revolution in Cambridge mathematics which was carried through, chiefly by Babbage, the younger Herschel and Peacock, about 1815.

Stratosphere Chambers

A MODERN Macaulay would assume that every schoolboy knows that the atmosphere surrounding the Earth consists of two distinct layers, the *troposphere* and the *stratosphere*. The former extends from sea-level up to a height of about 7 miles, and is characterised by unsteady conditions, such as winds and vertical currents, which lead to an approximately constant fall of temperature with increase of altitude of 2°C. per 1000 feet. Above this height the winds and currents cease, and the air remains comparatively steady with a constant temperature of about —54°C; the pressure and density have also decreased, to about one-fifth of their value at sea-level.

The absence of winds and storms in the stratosphere makes it a most attractive region for long-distance flying, but as with most aspects of aeronautics, the very features which make it so desirable are the ones which present the designer with his hardest problems. These problems arise from three main causes—the low pressure, the low temperature, and the humidity of the air.

For physiological reasons the pressure in a passenger cabin must never go below that corresponding to the atmospheric pressure equivalent to a height of 8000 feet. In addition, the apparent rate of change of altitude in the cabin should be limited to 300 feet per minute, the cabin temperature needs to be maintained at about 21°C., and finally humidity has to be controlled at 30%–60% of full saturation. The aircraft cabin must therefore be

constructed as a sealed chamber; when the plane goes above 8000 feet, the pressure in the cabin can be kept higher than the surrounding atmosphere by means of compressed air supplied by air compressors driven by the aircraft's engines. This air supply must also have its temperature and humidity controllable.

The problem presented by 'pressurisation' may be appreciated when it is realised that for an aircraft flying at 25,000 feet the atmospheric pressure outside the cabin is about 5½ lb. per square inch while that inside, corresponding to a height of 8000 feet, is about 11 lb. per square inch. This means that a pressure difference of 5½ lb. per square inch is trying to burst the cabin open. If the aircraft goes higher the pressure difference will increase. Apart from the considerations of structural strength to meet the pressure difference, the prevention of leakage of air from the many joints, window and door frames presents enormous difficulties. Temperature control must be capable of keeping the air in the cabin at about 21°C., in spite of the fact that the air being drawn in from outside is at +40°C. (or higher in the tropics) at sea-level, and possibly —70°C. above 30,000 feet. Thus both refrigeration and heating apparatus must be provided in the air ducts leading from the air compressors to the cabin. Since the humidity of the air depends on the temperature (hot air holds more moisture than cold) it follows that when flying at a height where the outside temperature is low the air which is drawn in and heated has a low humidity by the time it reaches the cabin. Consequently, for comfort moisture must be added to it.

As the crew of an aircraft are already fully occupied with controls, engine regulation, radio, navigation, and so on, all the air regulation must be as nearly automatic as possible. This naturally brings even greater design and operation difficulties.

When the demand for pressure cabins became insistent, it was soon discovered how difficult it was to predict how the installations would function under their actual working conditions, especially as detail design which seemed unimportant on the ground appeared to become major obstacles at 30,000 feet.

It soon became obvious that the only satisfactory method for obtaining data was to build a large sealed chamber in which all possible operating conditions could be simulated. Inside such a chamber the relevant parts for investigation could be placed, together with all the necessary instrumentation for recording its behaviour under the various conditions. If need be, human reactions could also be studied by observers actually inside the test fuselage.

Accordingly, a number of such 'stratosphere' research chambers have been, or are in the course of being built: notably by Normalair (a firm wholly devoted to this problem), de Havilland's, and Vickers-Armstrong (Fig. 5). The latter are now completing the world's largest stratosphere chamber at Weybridge. The scope of these chambers may be gauged from their specifications. That at de Havilland's has a working space 12 feet in diameter and 27 feet long; this space can be evacuated until the pressure corresponds to that at 70,000 feet, with the internal temperature controllable between +40°C. and —70°C. The Vickers chamber will have approximately the same operating range but is somewhat larger, the working space being 25 feet in diameter and 50 feet long.

While appearing to be costly and elaborate pieces of apparatus, these chambers in fact represent the most economical method of developing high-altitude aircraft, which in turn will provide the most economical air transport, and the rapid acceptance of their need, and consequent construction, by the British aircraft industry is to be welcomed.

Through a seventeenth-century Microscope

ANTHONY van Leeuwenhoek, one of the most successful of the pioneer microscopists, was born at Delft in Holland in the year 1632, about the time when men had first begun seriously to question many long-established superstitions and beliefs. His father died when he was young; and concerning the first forty years of his life there exists only meagre information, though Paul de Kruif made the most of it in the first and most brilliant chapter of *The Microbe Hunters*. Eventually he obtained a post in the administration of his native city. He became a friend of Jan Vermeer, and acted as Vermeer's executor upon the latter's death in 1675. Harvey's discovery of the circulation of the blood was supplemented by Leeuwenhoek's observation of the capillaries in the frog's foot. Leeuwenhoek was the first to observe blood corpuscles, the striping of muscle, and the structure of such things as hair and ivory. He first noticed definitely unicellular organisms, and recorded interesting facts regarding insect structure and the characters of rotifers. His investigations led him to become a firm opponent of the theory of Spontaneous Generation. In the course of these investigations he proved, among many things, that the real cause of oak-galls lies in the deposition of the eggs of an insect in the bark; that aphids and eels are viviparous; and that fleas do not originate from the dung of pigeons, but are propagated like other insects.

During the early part of his life Leeuwenhoek had learned to grind and polish lenses. He must have learned

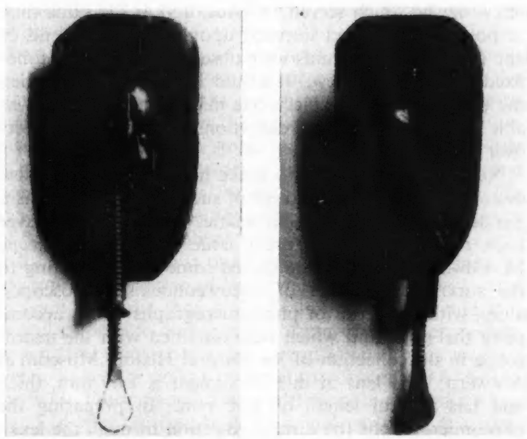

FIG. 6.—Back and front view of the Leeuwenhoek microscope in the Antwerp Natural History Museum. The lens is centred on a brass plate, 48 mm. × 26½ mm. The microscopic object would be impaled on the point of the screw device seen in left-hand photograph. (*By courtesy of the editor of The Microscope.*)

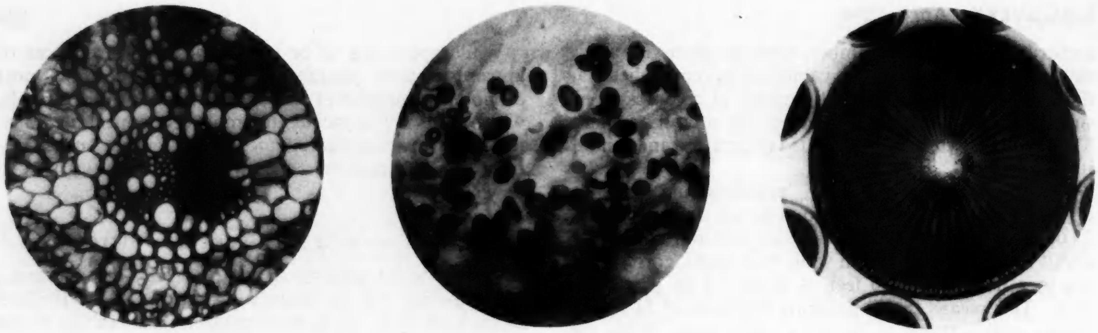

FIG. 7.—Three photomicrographs obtained with the microscope shown in Fig. 6. The magnification of each is 80 times. *Left:* cross-section of leaf of esparto grass; the details are sharply rendered. *Centre:* spores and tissue of a truffle (*Tuber brumale*); the limit of resolving power is being reached, and the processes on the surfaces of the spores show but feebly. *Right:* A diatom (*Arachnoidiscus*). All the delicate details are missing, the resolving power of the microscope being too low. (*By courtesy of the editor of The Microscope.*)

also that if he made these lenses, as we should say, of very short focal length, he could use them to make things appear very much larger than they did to his naked eye. Biographical accounts tend to concentrate upon his pioneer microscopical observations, and less notice has been directed to him as the maker of the microscopes which he employed for his discoveries. This neglect may be very largely due to the survival of only nine instruments from among the hundreds he is known to have made.

The microscopes which Leeuwenhoek made and used were of the type nowadays designated as 'simple', i.e., observations were made through one lens only, not through a system composed of separate objective and eye-piece (Fig. 6). To make a microscope, he would mount one of his tiny lenses, which might magnify anywhere between 50 and 250 times, in the centre of a plate of copper or silver. Then to one side of the plate he would affix an ingenious screw device which served to focus, and at the same time to position the object impaled upon the pointed end of one of the screws. Fluids were observed in capillary tubes fixed to the same screw. It would appear that he applied the principle of, one object, one microscope; thus he was able to make repeated observations on the same objects over an extended period.

Not only did he learn to make his own lenses, he also discovered how to make them of such excellence that as a grinder of simple, non-achromatic, lenses he has never been surpassed. In a recent issue of *The Microscope* M. Edward Frison has published some details relating to the surviving examples of Leeuwenhoek's microscopes, along with the series of photomicrographs which accompany this note, and which were obtained with the microscope in the collection of the Natural History Museum at Antwerp. The lens in this instrument is 1·09 mm. thick and has a focal length of 2·50 mm. In preparing the photomicrographs (by direct projection through the lens), no accessory apparatus was used save for a picric acid filter. Illumination was by an ordinary 60-watt bulb 50 cm. from the microscope, and in each case the entire area of the projected image is depicted, and the relative excellence of the results leaves one in no doubt as to the state of perfection to which Leeuwenhoek had brought his lens-making technique. In scrutinising these photomicrographs, the reader should take into account loss of the finest detail due to photo-mechanical reproduction.

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The first Man-made Mesons

THE U.S. Atomic Energy Commission last month announced the laboratory liberation of mesons, heretofore found only in cosmic rays. This discovery was made in the course of research for the Commission in the Radiation Laboratory of the University of California at Berkeley. This achievement, which has been described as one of the great milestones in fundamental nuclear science, depended on the use of the university's 184-in. cyclotron, the most powerful instrument of its kind in existence. A target of carbon was bombarded with a beam of 380 Mev alpha particles (helium nuclei). The nuclear disintegrations brought about by the impact of these high-energy particles on the nuclei of carbon atoms were recorded by means of special photographic plates, and among the particle tracks found on the plates were tracks which were unmistakably identified as those of negative mesons. (The kind of technique used for detecting the mesons was described in our article on 'The Photographic Plate in Atomic Research' by R. H. Hertz, DISCOVERY, 1947, Vol. 8, pp. 73–8.)

Professor Ernest O. Lawrence, who directs the Radiation Laboratory of the University of California, said in an interview that he expected the discovery to pave the way to new opportunities for understanding unsolved nuclear processes. He called the meson the best tool for studying the forces holding the nucleus together. He gave full credit to the discovery of 'artificial' mesons to the two men who made the experiments. They were Dr. Eugene Gardner, a radiation physicist who formerly worked on atomic energy research at the Oak Ridge establishment, and Dr. C. M. G. Lattes, a Brazilian scientist who went to Berkeley recently on a Rockefeller Foundation fellowship. The latter had previously spent two years on cosmic ray research at Bristol University. A formal report of their findings appeared in *Science* on March 12.

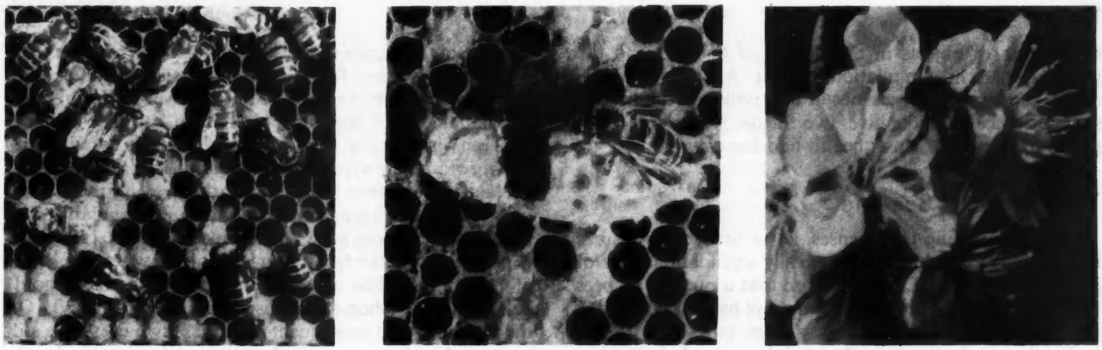


FIG. 1.—The different functions performed by the worker bee follows a definite sequence, which can be divided into three main periods. (*Left*).—In the first period she carries out nursery duties. This photograph shows nurse bees feeding larvae, and older household bees responsible for capping cells containing fully grown larvae. (*Centre*).—The second set of duties can be described as household duties, which include storage of nectar, sealing of cells, and comb-building. Here a worker is tearing down a queen cell. (*Right*).—Finally, the bee 'graduates' to foraging duties. This bee is seeking nectar from plum blossom.

Aspects of Bee Behaviour

COLIN G. BUTLER, M.A., Ph.D.

THE organisation of the social life of a colony of honey bees has for generations past intrigued man, and many have been the suggestions made in attempts to explain this phenomenon. Some of the earlier writers, including Virgil, believed that a king bee reigned over the inmates of each hive and directed their labours. It was not, indeed, until 1925 when Rösch published his findings on the division of labour amongst the worker population of a colony of bees that we began—and it was only a beginning—to understand something of the organisation of social life amongst bees.

Rösch showed that every worker bee is able to undertake all the tasks which present themselves to her, following, with advancing age, a definite sequence which is the same for each individual member of the population of a properly balanced colony. He showed that the life of the worker bee in such a colony is divided into three main periods during which she performs the following duties in turn: nursery work, household work, and foraging. The very first duty performed by the young adult bee is to clean out the lately occupied cells of the brood combs so that further larvae may be reared in them and, at the same time, she also helps to maintain a high and almost constant temperature in the brood nest. When she becomes about three days old she ceases to clean out cells, and from then until about the sixth day of adult life she is primarily concerned with feeding the older larvae with a mixture of honey and pollen which she takes from the stores of these foods within the hive. During this period she herself consumes large quantities of protein in the form of pollen, and certain glands in her head called the 'brood food' glands, which secrete a jelly-like substance very rich in protein, have been increasing in size until by the sixth day of adult life they are fully developed. From the sixth until about the tenth to fifteenth day of adult life, during which period her brood food glands continue to secrete more or less abundantly, she attends to the feeding of the very youngest larvae which, until they are about three days old and begin to receive a diet of honey and pollen, receive nothing but this special glandular food. By the end of this period of nursing the worker's brood food glands have once more become greatly reduced in size, and she enters into the second of the main periods of her adult life.

This second period commences on or about the fourteenth day with her first short flight from the hive, the so-called 'play' or first orientation flight. During the course of the next seven days the young bee is responsible for such matters as receiving the nectar that is brought into the hive by the foragers, storing and ripening it, seeing that the pollen brought in is likewise stored properly, general house cleaning, the secretion of wax and any necessary comb building, and, by making further orientation flights, she learns the position of the entrance to her hive relative to neighbouring objects in the apiary. Such things as other hives, bushes, and even stones, situated within a few yards of the hive, all come to serve as useful landmarks to the homing bee. Towards the end of this period in her life the young bee frequently helps to guard the entrance of her hive against robber bees and wasps.

By the time a bee is three weeks old she has learned to recognise the position of her hive in the apiary and to find it again, and she then embarks upon the third and last period of her life during which she collects water, nectar, pollen (and sometimes a resinous substance called *propolis* which is used for sealing up small spaces within the hive) in the field. During good flying weather in the summer when the field bees are very busy, this final period in a worker bee's life may last for anything up to three weeks.

If at the end of the period during which the young bee is performing her orientation flights, prior to becoming a fully fledged field bee, and is learning the position of her hive relative to neighbouring objects in the apiary she is captured at the hive entrance and released a short distance from her hive, she will find her way home by sight, by

recognition of objects in the vicinity of her hive and the position of her hive in relation to them. As soon, however, as she commences to seek nectar and pollen in the field at some distance from the hive, two further senses come into play and assist the young bee to find her way home.

The Forager's Bee-line

Before discussing these senses, let us first see how a bee behaves when she has found a really abundant supply of good-quality food. Let us suppose that a number of bees have found a dish of sugar syrup that we have placed on the ground one hundred yards away from their hive. These bees can be observed to fly straight out of their hive, 'make a bee-line' for the dish of syrup that they have previously found, settle upon it and immediately commence to feed and, as soon as they have filled their honey-stomachs, which will take about half a minute, return by the most direct route to their hive. Here they proceed to regurgitate the syrup that they have collected, passing it with their tongues to those of the household bees that are responsible at the time for the storage and ripening of food brought into the hive. These field bees then leave the hive once more and return to the dish for another load of syrup.

In one of a series of observations made during the summer of 1942 two bees were found to be visiting a dish of syrup placed on the ground about 360 yards from their hive. These two bees were each marked with a spot of quick-drying cellulose paint on the dorsal surfaces of their thoraces so that they could be readily recognised not only from all other bees but also from each other, one bee being marked red and the other blue. When this had been done continuous observation was kept on this dish for just over one hour and the number, duration and time of the visits of these two clearly marked bees to the dish were noted.

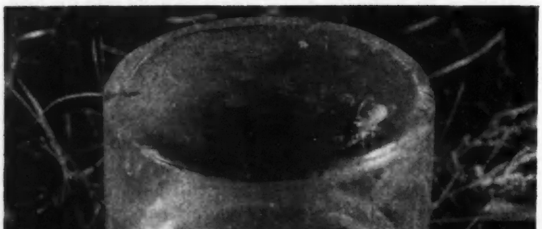


FIG. 2.—A dish-feeder of the type described, in which a constant supply of sugar syrup is made available to the experimental bees.

During this hour one of these bees paid sixteen visits to the dish and the other fourteen, the average length of time each bee spent on the dish being just over half a minute; the remainder of the time, that is to say the intervals between visits or the time spent each time in flying home, getting rid of the syrup, and flying out to the dish again, averaged about four minutes. In the evening these same bees were still visiting the dish with great regularity and must between them have already made at least 150 round trips, almost certainly without a break, between the hours of 11.26 a.m. (when observation on the dish commenced) and 4.25 p.m. (when it was discontinued for the day). On the following and subsequent days these two bees were still visiting this dish as regularly as ever. It should also be mentioned that in order to reach this dish they had to fly either over or very near many other dishes containing syrup of the same concentration and in the same abundance, and yet they never, so far as could be determined, deviated from their course in order to visit any other dish. It is now known as a result of this and other experiments that honey bees do in fact remain remarkably constant to one particular dish or small group of flowers to which they have somehow become attached, even though this dish or group of flowers may be surrounded by others of apparently equal attraction over which they are forced to fly in order to reach their especially favoured dish or patch of flowers.

It was also observed in the simple experiment that has been described that each of these bees took up a very definite and characteristic stance on the dish. One of the bees always chose a point of feeding on the west side of the experimental dish and the other selected a point on the north side. Neither bee ever moved more than a millimetre or two from her chosen position, and each assumed a characteristic attitude whilst drinking, one drinking from the side of the dish and the other settling head downwards on the reservoir which supplied the syrup to the dish.

Sensing Direction and Distance

Now it might perhaps be imagined that these two bees that were visiting this dish of syrup with such regularity were finding their way between the dish and the hive by means of sight, by the recognition of various landmarks. Undoubtedly sight, combined with the memory of various prominent objects seen on previous flights, did assist these two bees to find their way home from the dish but, as already mentioned, Wölf has shown that two other senses, *a sense of direction* and *a sense of distance travelled*, supplement the recognition of landmarks. Let us suppose that we place a dish of sugar syrup *exactly one hundred yards due north* of a fairly strong colony of bees. Sooner or later a few of the bees from this colony find this dish of syrup and commence to make regular journeys between their hive and the dish, transporting the syrup home as quickly as possible. As soon as half a dozen bees have settled down on our dish let us mark each of them with conspicuous spots of white paint so that we may readily recognise them even whilst they are on the wing. The next time that some of these marked bees visit the dish and have settled down to feed we pick up—very gently, so as not to disturb the bees—the dish with the bees still feeding on it, and move it to a point thirty yards due west of the original feeding place. We find that when the bees leave the dish they do not fly

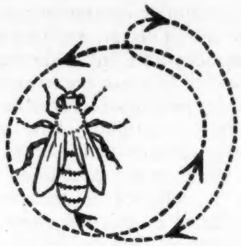
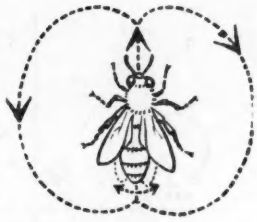


FIG. 3.—A bee is able to communicate to other bees where food is to be found by 'dance language'. This is the pattern she dances when the source of food is relatively near to the hive—the so-called Round Dance of von Frisch. (Figs. 3 and 4 come from von Frisch's paper in *Experientia*.)

FIG. 4.—As the distance increases, the dance pattern gradually changes until this pattern is reached. Here, in the so-called Wagtail Dance, the bee makes a half-circle to the right, then a straight run during which she waggles her abdomen, and then a half-circle to the left.



in a direct line to their hive, as they have been doing previously but instead they fly *exactly one hundred yards due south* and, failing to find their hive in this position, they commence to fly round and round in concentric circles of ever increasing size until they finally recognise some landmark which enables them to reorientate themselves and find their way home. Similarly, if the dish of syrup with the feeding bees on it is moved to a point due east of the original feeding place, the bees on leaving it fly due south, rather than south-west, for exactly one hundred yards before they realise that they are lost. The same behaviour is observed if the dish with its feeding bees is moved from its position due north of the hive to a new point just south of the hive. In this case the bees fly in a direction exactly opposite to that which would bring them back to their hive.

To carry this experiment to what appears to be almost an absurdity, the writer once removed the dish from its customary position and placed it on the roof of the hive. Most of the bees on leaving the dish failed to recognise the fact that they were actually on the roof of their home and flew away in search of it. The results of these experiments show very clearly that the honey bee not only makes use of local landmarks in order to find her way back to her hive, but also possesses knowledge of the direction from the feeding place in which her hive should lie and also of the distance that she has previously flown between her hive and the dish. Thus our experimental bees on leaving the feeding dish in each case flew due south for exactly one hundred yards in order to reach a point at which they expected to find their hive.

Guidance by Smell

In the course of these experiments the observer would have noticed that, although many hours or even several days may have passed before a single bee came near the dish of syrup that had been put out to attract the bees, once one or two bees had found the dish the number of bees visiting it increased rapidly. He may even have been led to wonder whether or not the bee that had first found the dish of syrup was able to convey knowledge of the presence and position of the dish to her sisters. Some writers, unable otherwise to explain the rapidly increasing population, have put forward the theory that the 'finder' bee leads other bees to the source of food either by actually flying along in front of them to it or by laying a trail of scent between the dish and the hive, or something of a similar nature. Actually as we now know, mainly on account of the work carried out by von Frisch, the finder bee does not leave a trail of scent or anything else to lead further bees to the food. She is, however, fully capable of informing them of the presence and source of a particular kind of nectar or pollen and, furthermore, the direction from the hive in which the flowers in which she has found this food are situated and the approximate distance between them and the hive. When a bee has found some profitable source of food in the field, such as a dish of syrup or some flowers in which a rich supply of pollen or nectar is available, she fills her pollen baskets or honey stomach as the case may be and returns to her hive. She will in all probability enter the hive and move on to one of the nearest combs. Here she proceeds to dance a little dance more or less vigorously. The more profitable the source of food the more vigorously she dances. Some of the younger bees that have just reached foraging age that are near to the dancing bee pay a great deal of attention to her, turn and face her, often follow her movements, and every now and then the dancer feeds to them small quantities of the nectar or pollen that she has collected. These small quantities of nectar or pollen can be shown to contain sufficient of the perfume of the kind of flower from which they have been collected to inform their recipients of the perfume associated with the flowers from which the nectar or pollen was obtained. Later some of these recipients will leave the hive in their turn in search of this perfume and thus of the flowers from which it and the nectar or pollen were obtained.

Communication by Dancing

The dance itself it somewhat variable, but fundamentally it consists of a series of figures-of-eight repeated at frequent intervals. If the source of food is located only a short distance away from the hive the two loops of the figure-of-eight are superimposed one on top of the other, but as the distance between the hive and the food becomes greater the two loops of the eight become more and more discrete until, when we reach the stage that the source of food is situated at a distance of about one hundred yards from the hive, a perfect eight with entirely distinct loops is being formed (Fig. 4).

As the distance becomes greater than one hundred yards a straight run of proportionately increasing length is interpolated between the two loops of the eight and during the performance of this part of the dance, the straight run, the dancer wags her abdomen rapidly from one side to the other. (Fig. 5.) Thus the dancer is able to indicate to her sisters the approximate distance between her hive and the source of food.

Finally it has been shown that the degree of inclination of the straight run, if present, to the vertical is an

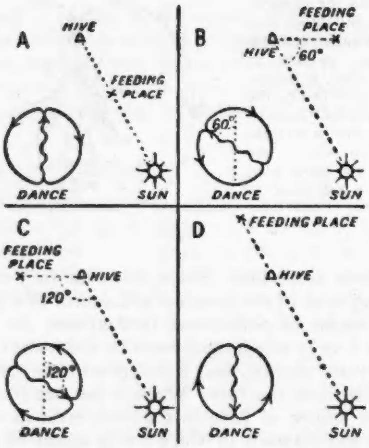


FIG. 5.—How a bee conveys to other bees the direction in which a profitable feeding place lies with respect to the hive. In *A*, the straight run (shown by wavy line in the diagrams since the bee is waggling her abdomen) is vertically upwards on the comb when the food source lies in the direction of the sun; if the food is in the opposite direction (see *D*), the straight run is vertically downwards. By varying the angle of the straight run to the vertical the bee can communicate the intermediate directions. (*Reproduced by courtesy of the editor of The Observer, based on von Frisch's diagram published in 'Experientia'.*)

indication of the direction in which the source lies relative to the position of the sun. If the straight run is made vertically upwards on the comb then the source of food lies in the direction of the sun at that time; if the run is performed vertically downwards the source of food lies in exactly the opposite direction, and so on. Thus a bee is able to inform her sisters of the richness of a source of food, of the kind of food, that is to say whether it be pollen or nectar; of the perfume of the flowers in which this food is to be found, and of the direction from the hive in which these flowers lie and their distance from the hive!

Division of Labour

Although we know quite a lot about the division of labour amongst the worker bees of a colony before they become field bees, that is, in general, to say before they are three weeks old, unfortunately we know very little about the division of labour amongst the field bees. Many observers are convinced that some form of division of labour does exist between the field bees of a colony which ensures, under reasonably favourable circumstances, that all the bees do not go off to collect nectar, resulting in the collection of a surplus of carbohydrate and a shortage of protein. The order, if such exists, in which the several field duties are undertaken by every individual worker bee has not yet been determined with any certainty. One or two observers working with small colonies composed entirely of very young bees have come to the conclusion that, generally speaking, nectar is collected by the younger foragers whilst pollen is collected by the older ones, and water is collected by the youngest foragers of all. The colonies upon which these observations were made were not, of course, properly balanced ones and these results are, therefore, open to question. Indeed Rösch himself was unable to discover any definite sequence of duties performed in the field, and more recent research strongly supports the view that whereas there may be a tendency for the younger field bees to collect nectar and the older ones pollen, this is little more than a tendency, and the work performed by a field force of a colony of bees at any given time is probably less dependent upon age than upon such other factors as the nutritional requirements of the colony at that time, and, perhaps, the relative availability of nectar and pollen in the field. It is, of course, well known that a certain number of bees collect nectar and pollen simultaneously from the flower of their choice, and that certain flowers contain so much pollen and are constructed in such a way that the visiting bee, even if she should only be desirous of collecting nectar, is compelled to collect on her body a great deal of pollen as well. It is, however, less well known that in certain circumstances a bee will, after combing the pollen off the hairs of her body, instead of transferring this pollen to her pollen baskets for transport back to her hive, deliberately drop the pellet of pollen on to the ground. Such behaviour can frequently be observed amongst bees that are working sun-flowers for nectar. There is thus some evidence that whilst for the most part the honey bee is a creature of habit blindly doing certain things in response to certain stimuli, she is capable on occasion of breaking the general rule and doing the unexpected.

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FIG. 1.—The radar aid called GCA (Ground Controlled Approach) enables planes to be landed on fog-bound aerodromes. This picture shows a Viking aircraft coming in to land under the direct control of the GCA trailer, which is stationed alongside the runway.

GCA: Air Safety in Fog

A. W. HASLETT, M.A.

A LOST Londoner looking for his house on a foggy night could be guided to it either by providing him with equipment with which he could himself 'see' through the fog, or by installing a 'controller' at any convenient point, and giving the 'controller' equipment with which he could see and guide the Londoner. The advantage of the second method would be that the amount of equipment which the Londoner had to carry would be as small as possible. He would need a miniature radio set on which he could listen to the controller's directions, but nothing more. Also, because the controller would be operating from a fixed position, he could make use of more elaborate equipment than the Londoner could readily carry on his walk. As against these advantages, the Londoner would need to feel a high degree of confidence both in the controller personally, and in the equipment on which his directions were based. He would have to be prepared to 'take ten paces forward', 'turn half right', 'now advance twenty paces', and so on until he received his final direction that another five paces, say, would bring him to the house. The directions might be perfectly judged, but without a number of clear-weather trials, when he could see for himself that the controller knew his business, he might hesitate to step out boldly in a fog. Finally, it would be necessary for him to understand clearly and quickly the controller's directions; suppose, instead of a Londoner, the controller had to guide a Frenchman or a Dutchman, then it would be necessary for the Frenchman or Dutchman to be fully familiar with 'controller's English'.

There is the same choice of methods, with roughly the same advantages and drawbacks, in the case of an aircraft approaching an airport, also in fog. As with the Londoner, it is possible in principle to provide the aircraft with all necessary equipment for obtaining its own position. Alternatively, all special equipment can be concentrated at the airport, and a controller on the ground can direct the aircraft up to the final stage when the pilot can be told the runway is dead ahead, at such-and-such distance, and so far beneath him, and it is now up to the pilot to make his landing.

But, although the choice is the same in principle, there are two further points in the case of the aircraft which favour the ground control method. The first is that it is impossible at the present time to concentrate the whole of the position-finding equipment in the aircraft. The most that can be done is to provide the aircraft with equipment, which in conjunction with other equipment on the ground can enable the pilot to make his own 'blind approach'. In other words, what the pilot will be 'seeing' will not be the aerodrome itself or the runway itself, but various bits of automatically operated radio or radar equipment so designed and placed as to give him the information he wants. That means that not only must the aircraft be specially equipped, but the special equipment in the

aircraft must match the special equipment installed at the airport. In an ideal and internationally standardised aviation world—towards which, through the International Civil Aviation Organisation, we are slowly moving—this would present no difficulty. But for immediate purposes no such assumption can be safely made, so that there is an inherent advantage in a 'ground control' system which makes no special demands on aircraft equipment. The second point is one which any car-driver will readily appreciate. It is that there is a difficulty of visual adjustment in flying for many minutes with attention concentrated on luminous instruments, and then switching back for landing into the world of fog and possibly darkness outside. Yet this is the position with any pilot-operated system of 'blind approach'. To some extent it is true that this objection applies to any system which does not include 'blind landing' in the full sense as a normal procedure. But with ground control, it can at least be said that no further attention to instruments is necessary than in a normal landing made in clear conditions.

For such reasons the Ministry of Civil Aviation is now proceeding with a network of Ground Controlled Approach (GCA) installations covering the chief British airports. Those already equipped and in operation are London Airport and Prestwick. Speke (Liverpool) is next on the list, to be followed by Northolt, Belfast and Bovington in that order. That the system is justifying itself is shown by the fact that in one recent winter month more than one in five of all landings at London Airport were GCA-controlled. Of these 50 were practice runs, 43 were made in conditions of moderate visibility, and a further 135 landings were made under 'Category C' conditions—that is, with visibility less than two miles and cloud-base below one thousand feet. The main obstacle to more rapid expansion is the need for ground-crew training. There are six individuals in each GCA crew, and even if operation is confined to the period from 8 a.m. to 9 p.m., as at London Airport, two ground crews are wanted to give reasonable service. The London installation was at first operated by R.A.F. personnel. The training of civilian crews is still being undertaken by the R.A.F., and this is being done at the Central Signals Establishment at R.A.F. Station, Watton, in Norfolk.

The equipment, which at present is mounted in trailers, is similar in many respects to that developed during the war for the night control of fighters. It provides for the measurement of the range, direction and angle of elevation of the aircraft by radar methods. Each of those measurements is simple in principle. That of range is similar to any other form of echo-sounding. If a man stands at a distance from a cliff and shouts at it, he can time with a stop-watch the interval before the echoing shout comes back to him from the cliff, and if he knows the speed at which sound travels in air he can calculate what his distance must be from the cliff. In this, as in any other form of radar, the man's shout is replaced by a succession of short, sharp radio pulses; the echoes from the aircraft are radio echoes; and the distance of the aircraft is obtained from knowledge of the speed at which radio waves travel. As will probably also be familiar, the echoes are displayed on a cathode-ray tube, similar to those used in television receivers. Again, there is nothing which is difficult in principle about the method of observation. The problem is to measure the time interval between two readings—corresponding with the transmitted pulse and the echo pulse respectively—and the only difficulty is that this interval may be no more than a few millionths of a second. It could be done in theory with an ink-recording pen, such as is used in a barograph, and a drum of paper revolving at a high enough speed. But in practice it would be impossible to make a pen that was light enough, and sufficiently well balanced, to give two separate deflections at so short an interval. The cathode-ray tube does the same job electrically. It is a timing device, neither more nor less, which is capable of unusually quick response and which, for convenience, is calibrated in miles or feet instead of seconds.

The other two measurements—those of direction and angle of elevation—are even more direct. The radio transmissions are beamed, through reflection from a metal mirror, to give the exact equivalent of a radio searchlight. The position in which the strongest echo is received is, therefore, the one in which the aerial system is 'looking' directly at the aircraft.

The remaining specifications are suggested by the problem they are designed to solve. The narrower and more highly directional the radio beam is made, the more difficult is it to pick up and follow any distant object.

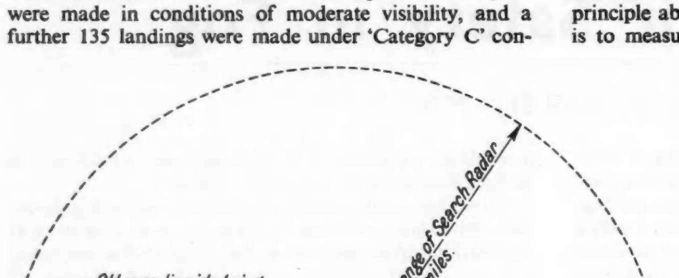

FIG. 2.—The layout of a GCA installation.

But at the stage of final approach to the runway the highest possible accuracy is needed, and so the narrowest possible beam. It follows that the same aerial system could not be suitable for both distant and close control. The solution, in GCA, has been to accept the difficulty, and provide two independent radar sets for the two jobs. The search system, used in the first stage and for the control of waiting aircraft, operates on a wavelength of about 10 centimetres and uses an aerial system deliberately designed to produce a comparatively wide beam. The standard beam width is about seven degrees horizontally, and eight degrees in elevation. This beam is continuously rotated and provides the 'directors' with a continuous picture of all aircraft within about 30 miles of the airport at 4000 feet. About 1500 feet is, however, the preferred altitude for the approach flight. Normally, the first GCA director takes the aircraft through the stages of identification and coming into circuit, and the second director guides it to a range of about 7½ miles at a height of 1500 feet and on a course directly approaching the runway. Thus far control is based on the search radar. This, it should be noted, remains in continuous operation so that, even while one aircraft is on the last stages of approach and landing, independent directions can be given to other aircraft waiting.

The precision system is designed to work at a maximum range of ten miles but, as indicated, does not normally take over until 7½ miles from the runway. Also, its scan is limited to the final direction of approach, since the second director will already have brought the aircraft into correct alignment. A wavelength of about 3 centimetres is used, compared with 10 centimetres for the search system. The reason is that the shorter the wavelength the smaller are the mirrors needed to produce any specified narrowness of radar beam.

For convenience of operation, the precision system is in turn split into two components, each with its own aerial and display system. One of these records the horizontal direction of the aircraft, and the other its elevation, power being automatically switched between the two, so that each provides a continuous record. It might be asked at this point whether this division of function really does make for convenience, and whether it would not be simpler to use a single narrow-beam radio searchlight, so directed that the aircraft was kept continuously in view. The answer is that this would imply highly skilled operation, with a risk even so that the aircraft might be 'lost' momentarily. It is safer to work on the 'scanning' principle, with the radio beam sweeping quickly over the whole area within which the aircraft could be, and recording its position at each sweep. But the use of a single aerial to give a combined vertical and horizontal scan, apart from being complicated mechanically, would mean that there were too long intervals between the picking up of successive echoes from the aircraft. The best combination of speed and reliability is, therefore, to allow one aerial to sweep in a horizontal plane, and a second aerial in a vertical plane, so that independent measurements of direction and elevation are obtained. The horizontal area covered is about 20°, and a typical layout is shown in Fig. 2. It will be seen that the GCA equipment is offset from the runway—as, obviously, is necessary for safety of the equipment and its operators—and that for this reason the horizontal coverage is not symmetrical. The area swept in a vertical plane is similarly limited to about 7°. The same figure shows also the more distant and all-round coverage given by the search system, and a typical approach course.

An important element in the system is that no calculations of any kind are required from the 'precision controller' during the final stages of approach. The approach will have been determined in advance, and the equipment is so designed that the operators can give him the information he wants in the form in which he needs it—i.e., the extent to which the aircraft is above or below, or to left or to right, from its prescribed path. This is done by a mixture of manual and electronic computation, with which the controller need not concern himself. Also, the greater part of the radar equipment is duplicated, and standby units are maintained in such condition that they can be brought rapidly into full operation in the event of any failure of the 'channel' which is in use. On the other hand, it is not usual practice to provide more than one GCA unit per aerodrome. The complete unit is fully mobile, and with sites for each runway already prepared can be quickly shifted as changing wind conditions may require.

There remains the final question of a true 'blind landing'. GCA, as its name implies, is an 'approach' and not a 'landing' system and, following a recent landing crash at London airport, instructions have been issued that GCA is only to be used, other than in emergency, when local visibility at the airport reaches a prescribed minimum standard. This is to ensure that, having been guided to the runway, the pilot shall be able to see it in sufficient time to make his own landing. On the other hand, both experimentally and in emergency, complete blind landings have been made under GCA direction and without sight of the runway.

A MILLION-YEAR-OLD 'WORKSHOP'—*Contd. from page 122.*

months—equipped with the finest apparatus and enough funds to secure skilled and unskilled labour—to study the skull's age.

"Doubtless," Dr. Paterson sighs, "Britain has the biggest wealth of fossil human remains known anywhere, and the chances of finding the 'missing link' here are great. But widespread apathy in these matters is disheartening, as is the lack of interest in the early Stone Age remains. Near Thetford lies the oldest Stone Age workshop site in Europe, the only place in Europe where one can be certain to find within a few minutes' digging a tool made and left there—about 400,000 years ago—by Old Stone Age Man. Yet the site lies in ruin and neglect."

Now we are to see the remains of two of the oldest 'Britons' depart from these shores, while students from abroad come to find our earliest ancestors and remove them, just as English archaeologists did in the past in countries then considered backward. And all because British archaeologists are short of the £2,000 to £3,000 needed for three or four years' excavation that ought to be made in an attempt to unearth the bones of the Norfolk Man.

FIG. 1.—The Observatory's new home, Herstmonceux Castle in Sussex.

The Royal Greenwich Observatory

SIR HAROLD SPENCER JONES, F.R.S.

THE Royal Observatory, the oldest scientific institution in Great Britain, was founded by King Charles II in 1675 for the practical purpose of assisting navigation. At that time there was no method of finding the longitude at sea. The suggestion had been made that the longitude could be found by measuring the distances of the Moon from adjacent bright stars. When this was brought to the notice of the King, he referred it to a committee of scientific men for a report. The report was prepared by the Rev. John Flamsteed (1646–1719), who had acquired a considerable reputation as a practical astronomer. It pointed out that the positions of the Moon given by the best tables differed as much as one-third of a degree from the true positions, while the star catalogue of Tycho Brahe, which was nearly a hundred years old, was erroneous and incomplete. The method was in theory correct but could not be applied in practice "till both the places of the fixed stars were rectified, and new tables of the Moon's motion made, that might represent her place in the heavens to some tolerable degree of exactness; for which a large stock of very accurate observations, continued for some years, was altogether requisite."

Charles II decided to found an observatory where the required observations could be made, and to appoint Flamsteed as the astronomer to do the work. He provided a site on the highest ground in his park at Greenwich and appointed Sir Christopher Wren as the architect. The observatory was erected at a cost of £520, defrayed by the sale of spoilt gunpowder. There Flamsteed began his observations in 1675. His position was not an easy one, for he was provided neither with instruments nor with assistants. His friend and patron, Sir Jonas Moore, presented him with two clocks by Tompion, and a large iron sextant, with which, working single-handed, he made 20,000 observations in thirteen years. But these observations gave only relative positions. It was not until 1689 that Flamsteed was able to install a large mural arc and to derive absolute positions. In all, he spent upwards of £2,000 above his meagre salary of £100 a year in furnishing instruments and in hiring assistants and computers.

Flamsteed's Star Catalogue

Flamsteed's observations were planned with a careful attention to accuracy. They are, in fact, the earliest from which the phenomenon of aberration is clearly deducible. He introduced new methods into practical astronomy, many of which are in use today, and an immense mass of computations was carried out in a systematic and orderly manner to correct the theories and to improve the tables of the Sun, Moon and planets, and to elucidate intricate points in practice and theory. The collected observations, including his great star catalogue of nearly three thousand stars, were printed at his own expense as the *Historia Coelestis Britannica*. He died in 1719, when much of the printing still remained to be done. This work was the first great contribution to science given by the Greenwich Observatory to the world.

Edmond Halley (1656–1742), the Savilian Professor of Geometry at Oxford, was appointed Astronomer Royal in succession to Flamsteed. Halley was a man of great originality and versatility, eminent in many branches of science. His authority in astronomical matters was so great that, although he was 63 years of age, no other appointment was possible. He found the Observatory devoid of equipment, for Flamsteed's instruments, which he had paid for out of his own pocket, had been removed by his widow. Halley obtained a grant of £500 from the Board of Ordnance, with which he procured an 8-ft. mural quadrant and a small transit instrument.* In order to improve the current tables of the Moon for the purpose of determining longitudes, he planned to observe the Moon through a complete revolution of its nodes—nearly nineteen years—a task which, in spite of his advanced age, he completed. His observations and his general astronomical tables were published in 1749.

Halley was succeeded by the Rev. James Bradley (1693–1762), the Savilian Professor of Astronomy at Oxford, a great practical astronomer and skilful observer. Bradley had already acquired fame by his discovery in 1728 of the phenomenon of the aberration of light, from observations with a 12-ft. zenith sector of the zenithal star, Gamma Draconis. He continued his observations of this star through a complete revolution of the Moon's nodes, and in 1748 announced the discovery of the nutation of the Earth's axis, the cause of which he correctly explained.

Bradley added two mural quadrants and a transit instrument to the equipment, the cost being defrayed out of a grant of £1,000 provided by the Admiralty from the sale of old naval stores. His zenith sector was also bought for the Observatory out of the grant. With these instruments some 60,000 observations of the fixed stars were made between 1750 and 1762, with the aid of one assistant. Bradley determined the laws of atmospheric refraction and was the first to introduce corrections for the temperature of the air and for the height of the barometer. His observations surpassed in accuracy any made up to his time: they are the earliest which are accurate enough to be of use to the astronomers of today.

The Rev. Nevil Maskelyne (1732–1811) was appointed Astronomer Royal in 1765, on the death, after a brief tenure of office, of Bradley's successor, the Rev. Nathaniel Bliss. Maskelyne took a great interest in practical navigation. He convinced himself by trials at sea that the method of lunar distances had at length become a practicable one, and that, with the aid of the new tables of the Moon, prepared by Tobias Mayer and published at the expense of the Board of Longitude, it was capable of determining the longitude with satisfactory accuracy.

* See glossary on pp. 118–19.

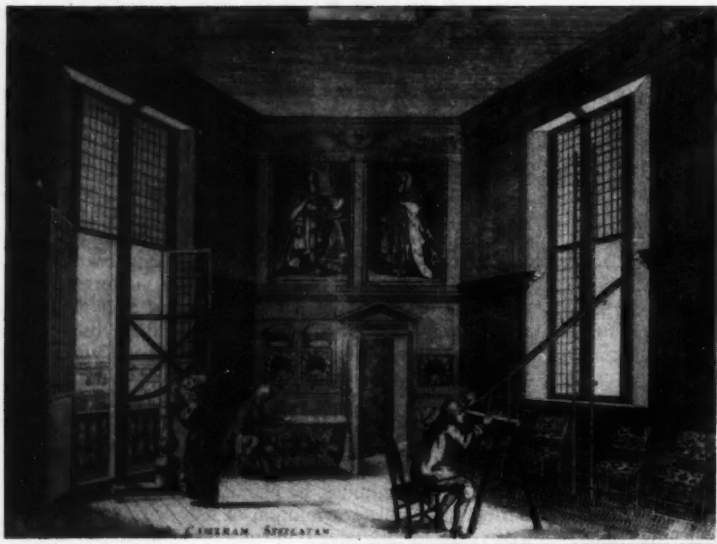

FIG. 2.—Interior of the Octagon Room in Flamsteed's times showing the two Tompion clocks behind table, and the quadrant with which most of the observations were made from 1675 to 1689.

FIG. 3.—The Royal Observatory as it was in Flamsteed's time.

FIG. 4.—A general view of the Observatory as it is today. The photograph shows the Wren building with the Time Ball on the roof.

Maskelyne provided a most valuable aid to navigation in the preparation of the *Nautical Almanac*, first published for the year 1767. He continued to produce it annually for forty-four years until his death. The invention of the marine chronometer by John Harrison, a Yorkshire carpenter (1693–1776), had provided a practical solution of the longitude problem, but astronomical observations were still required as a check on the error and rate of the chronometer.

Various improvements to the instruments and in the methods of observation were made by Maskelyne. He gave special attention to observations of the Moon to obtain data for the correction of Mayer's Lunar Tables. The Sun, planets, and thirty-six fundamental stars were regularly observed. His determination of the proper motions of these stars provided the data used by William Herschel to derive the motion of the Sun in space. In 1774 Maskelyne made the first measurement of the density and mass of the earth, from observations of the deflection of the plumb-line to the north and south of the mountain of Schiehallion. A mean density of 4·7 times that of water was obtained, a value which agrees with the true value within the uncertainty of the estimate of the mass of the mountain.

The progressive improvement in the accuracy of observation was continued under John Pond (1767–1836), who succeeded Maskelyne in 1811. The construction of a new mural circle, ordered by Maskelyne, was completed in 1812, and a 5-in. transit instrument replaced Bradley's small one in 1816. Pond introduced the use of the mercury horizon for determining instrumental flexure and the position of the nadir point. His catalogue of the positions of 1,112 stars, completed in 1833, was the most valuable contribution of the period to positional astronomy.

First Public Time-signal

In 1818 the control of the Observatory passed from the Board of Ordnance to the Board of Admiralty, and in 1821 the charge of chronometers used in the Royal Navy was transferred to the Observatory. The first public time-signal was inaugurated in 1833; it consisted in the dropping of a time ball at 1 o'clock p.m. daily from the top of a mast erected on the Wren building. Ships in the adjacent reaches of the river and in the docks were thereby enabled to regulate their chronometers.

During the later years of his tenure of office Pond's health was failing, his first assistant was inefficient, and the routine work of testing chronometers occupied an unduly large portion of the time of the small staff. The Observatory consequently fell into a state of disrepute. When Pond resigned in 1835, George Biddell Airy (1801–92) was called in to reorganise the Observatory. Airy had been elected Lucasian Professor of Mathematics at Cambridge in 1826, and Plumian Professor of Astronomy, with the direction of the new Cambridge Observatory, in 1828. A man of rigid routine, a strict disciplinarian, with wide interests and of exceptional ability, he was the ideal man for the task. During his long tenure of office the Observatory acquired a great reputation: he became the most commanding figure in the astronomy of his time, and was called in to advise the Government on a great variety of matters. He was, for instance, chairman of the Commission responsible for the restoration of standards of length and weight after their destruction in the Great Fire at the Houses of Parliament. On the development of iron ships he devised methods, which are still in use, for the correction of ships' compasses. He also prepared the report on the gauge to be adopted as standard by railways.

The meridian observations, which formed the traditional work of the Observatory, were continued systematically and with great energy, special attention being paid to the planets, the observation of which had been much neglected by Pond. An altazimuth instrument was installed in 1847 to enable observations of the Moon to be obtained in parts of her orbit where she could not be observed on the meridian. A large transit circle, to do the work previously done by the transit instrument and the mural circle, was designed by Airy and brought into use in 1851. This famous instrument, which was later to define the prime meridian of longitude, has continued in use to the present time: more than 650,000 observations of the Sun, Moon, planets and stars have been made with it. A natural development of the meridian work, made possible by the introduction of telephonic communication, was the distribution of time to the Post Office, to the railways, and to the Admiralty dockyards. Greenwich Mean Time was not adopted as the legal time of Great Britain until 1880. Before that date local mean time was often used, but the growth of railway communications had resulted in the general use of G.M.T., which was popularly known as Railway Time.

Magnetic and Meteorological Department

Airy soon saw the need for the extension in new directions of the work of the Observatory, which had hitherto been confined to positional astronomy. A magnetic and meteorological department was established in 1840. At first, magnetic observations were usually made at intervals throughout the day and night, but in 1848 continuous photographic registration was introduced. The observations were continued at Greenwich until 1923, when the electrification of the local railways necessitated the removal of the instruments to a new site, a separate magnetic observatory being established at Abinger in Surrey. The Royal Observatory has the longest continuous series of magnetic observations in the world.

The association between terrestrial magnetic disturbances and sunspots suggested the need for these related phenomena to be studied together. Accordingly, in 1873 a photoheliograph was installed for the regular daily photography of the Sun. Similar observations were also initiated at the Cape Observatory (South Africa), the photographs being sent to Greenwich. The combined series provides a practically continuous record of the Sun's surface, which has proved invaluable in a variety of investigations.

Two equatorial refractors were added to the equipment; the Merz 12¾ in., added in 1858, was a large instrument at that time. Observations of comets, double stars, and of planetary markings were made. With the birth of astrophysics, a spectroscope was added in 1874 for visual observations.

The new developments in the work, and the great activity under Airy's regime, had involved a corresponding increase in staff. In the first 150 years of its existence the

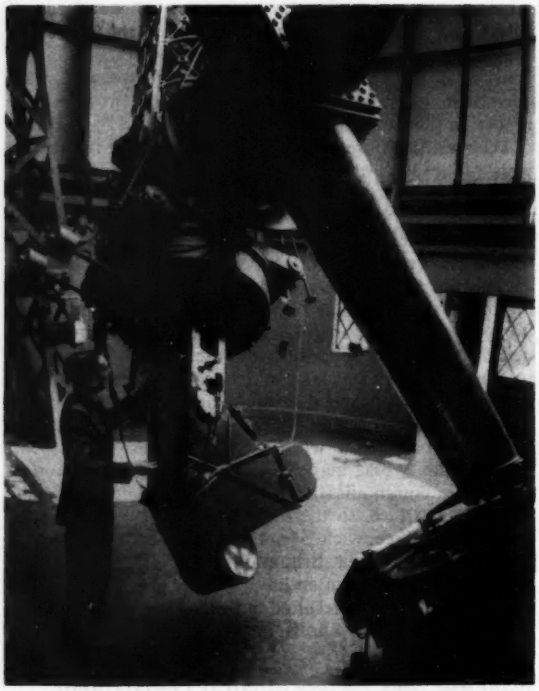

FIG. 5.—The Yapp 36-inch reflector with slit spectroscope attached.

work of the Observatory had been largely the personal work of the Astronomer Royal. Now, however, it was on the way to becoming a large institution, with a variety of programmes of work in which the whole staff co-operated. It is possible to refer only to some of the principal developments since 1881, under the administration of Sir William Christie (Astronomer Royal 1881–1910), Sir Frank Dyson (Astronomer Royal 1910–33) and the writer.

The application of photography to astronomy has led to great and rapid developments. One of the first projects to which photography was applied was the *Carte du Ciel*—a photographic chart and catalogue of the whole sky, in which a number of observatories co-operated, using similar astrographic telescopes of 13-in. aperture. Greenwich assumed responsibility for the cap of 25° radius round the north celestial pole. This region of the sky has become peculiarly a Greenwich region, many programmes of observation having been concentrated on providing additional information about the stars in it. The region was completely re-photographed after about twenty-five years in order to determine the proper motions of the stars. The distances of many of the stars have been measured with the 26-in. refractor, presented, together with a 30-in. reflector, by Sir Henry Thompson in 1894.

A 28-in. visual refractor was added in 1894, and has been used mainly for double-star observations. In 1931 Mr. W. J. Yapp presented a 36-in. reflector, together with a slitless spectrograph and a slit spectrograph with one-prism and three-prism dispersions. These have been used for the measurement of the colour temperatures of stars, and for general spectrographic investigations.

In 1884 the State Department of the United States convened a conference in Washington to obtain international agreement on the choice of a prime meridian, and the establishment of a zone time-system based on that meridian. The Greenwich Observatory had been so long and so closely concerned with the needs of navigation that no alternative to the meridian of Greenwich was seriously considered. The meridian through the centre of the Airy transit instrument was adopted as the prime meridian, and a system of time zones based on Greenwich Mean Time was recommended and is now in almost universal use.

Greenwich Time

Meridian observations have continued to be an important part of the work of the Observatory. To meet the requirements for higher precision, a new reversible transit circle was installed in 1936. A wider dissemination of accurate time was made possible by radio. The British Broadcasting Corporation's 'six pips' time signals were inaugurated in 1924. Special rhythmic time signals for navigational use have been sent out twice daily from the

GLOSSARY

ALTAZIMUTH INSTRUMENT is, as the name implies, an instrument for measuring the altitude and azimuth of a star. It is essentially a transit circle which instead of being fixed in the meridian can be turned into any azimuth, a horizontal graduated circle being used to determine the azimuth.

EQUATORIAL REFRACTOR is a refracting telescope (i.e. one in which a lens, not a mirror, is used to bring the light to a focus with an equatorial mounting). In this form of mounting the main or polar axis is parallel to the axis of the earth; a second, or cross axis, perpendicular to the polar axis is provided as a telescope must be capable of motion about two axes in order to be able to point in any desired direction. With this kind of mounting, when the telescope is pointed towards any celestial object, it is only necessary to turn the telescope about the polar axis at a rate equal to that of the earth's rotation (i.e. one complete rotation is a sidereal day) for the object to remain in the field of view. Rotation at the required rate can be conveniently given by a clockwork mechanism.

MURAL QUADRANT. This now obsolete instrument consisted of a large metal graduated quadrant placed exactly in the plane of the meridian against a solid wall to which it was firmly attached. A telescope (or, in the earliest form, a sighting arm) pivoted at the quadrant's centre was attached to a guide, movable along the quadrant. The instrument was invented by Tycho Brahe about 1577 and used for measuring the meridian altitudes of celestial bodies.

NADIR POINT is the point vertically downwards, and therefore opposite to the zenith point. When a graduated circle is used to determine the position of a telescope, it is necessary to fix some convenient point on the circle as a zero of reference. The position in which the telescope points vertically downwards (i.e. towards the nadir point) is conveniently determined by the use of a mercury horizon; the graduation of the circle being read for this position of the telescope, the position for any other circle reading becomes known.

SLITLESS AND SLIT SPECTROGRAPHS. In a slit spectrograph the image of a star formed by the telescope is focused on to a narrow slit and, with the usual arrangement of collimator and camera, as in a laboratory spectroscope, a photograph of the spectrum can

Rugby wireless station since 1927. These signals, of world-wide range, enable the navigator to check his chronometers, and have made the old method of lunar distances obsolete. The Post Office 'speaking clock', installed in 1936 and controlled by hourly signals from the Observatory, has made Greenwich time available by telephone everywhere in Great Britain. At the same time the precision of the time service has been greatly improved to meet practical requirements. The Observatory now bases its time entirely on quartz crystal clocks, eighteen of which have been installed. A 10-in. photographic zenith tube, of special design, is now under construction and will greatly increase the accuracy of time determination.

Expeditions have been sent from time to time to various parts of the world to observe total eclipses of the Sun. Mention may be made of the expedition to Brazil for the eclipse of 29th May, 1919, which provided the first confirmation of Einstein's prediction of the bending of rays of light passing near the Sun.

Greenwich was a village in the country when the Observatory was established in 1675. As a result of the growth of London, particularly during the last few decades, the Observatory is now surrounded by closely built-up areas, with many industrial plants in its vicinity. The smoky atmosphere, and the bright sky at night from the glare of London, have caused a progressive deterioration in the conditions for astronomical observations. The installation of larger and more powerful telescopes at Greenwich could not be justified. In spite of the ties of long tradition, the removal of the Observatory from Greenwich had become necessary if it were to continue to make important contributions to the advancement of astronomy. Proposals were submitted to the Admiralty, and as a result, after a large number of possible sites had been investigated, Herstmonceux Castle in Sussex (built in 1440), together with some 370 acres of surrounding land, has been acquired. The first stages of the removal of the Observatory to Herstmonceux are now in progress. The Government has agreed to provide a large reflector of 100-in. aperture, the use of which is to be shared between the Royal Greenwich Observatory (by which name the Observatory will in future be known) and the other observatories of Great Britain. This powerful new instrument will in due course be erected at Herstmonceux. After 272 years at Greenwich, a new era is now opening in the long history of the Observatory, rich with opportunity and promise for the future.

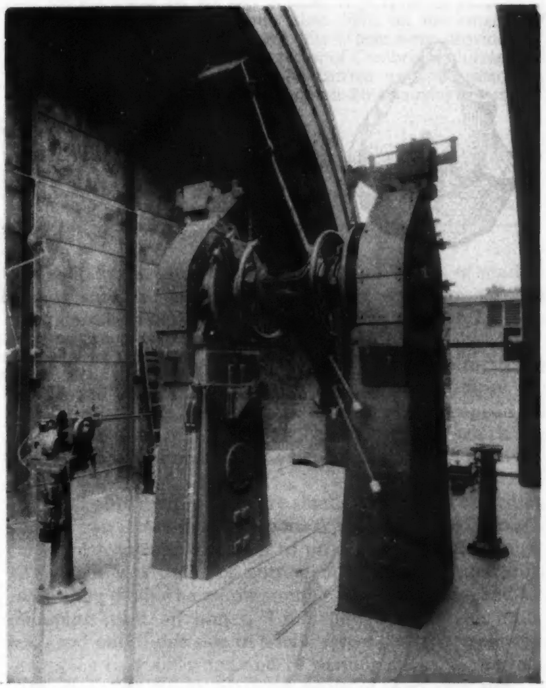

FIG. 6.—The new Reversible Transit Circle.

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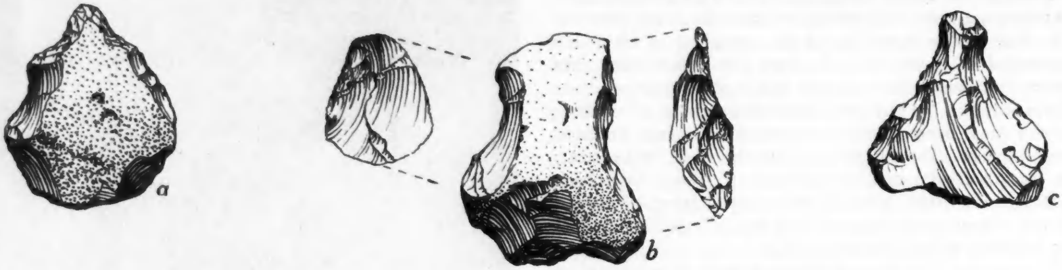
The Royal Observatory, Greenwich. A glance at its history and work. E. W. Maunder (London, 1900).

The Royal Observatory, Greenwich. H. Spencer Jones (Revised Edition. London, 1946).

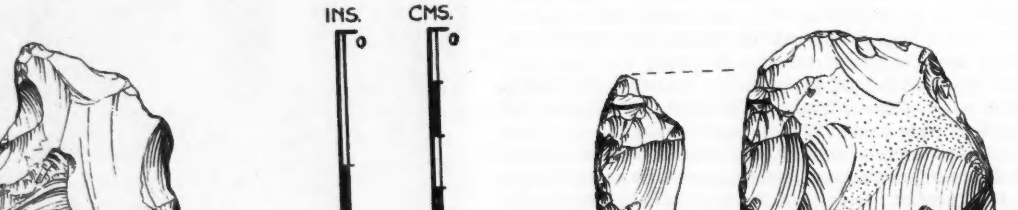
be obtained, in which emission or absorption lines or bands appear in the spectrum. The use of a slit is necessary for the study of fine detail, and also when it is desired to photograph a comparison spectrum from a terrestrial source in order to obtain absolute wavelengths. But a narrow slit is very wasteful of light and for some purposes is not essential. In such cases it is convenient to dispense with the slit, thereby greatly reducing the length of exposure required. A secondary mirror is used in the telescope which gives a parallel, instead of a converging beam of light; this parallel beam is dispersed by the prisms and brought to a focus by the camera lens. The slitless spectrograph can give information that is not readily obtained with a slit spectrograph; when, for instance, a small gaseous nebula is photographed with a slitless spectrograph a series of discrete images is obtained, from which information about the distribution through the nebula of the atoms responsible for each radiation is obtained. The slitless spectrograph was used at Greenwich for measuring the intensity of the continuous spectrum in regions free from absorptions, in order to obtain information about the energy distribution and therefore about the temperatures of the stars.

TRANSIT INSTRUMENT consists of a telescope which is supported from pivots at the two ends of a cross axis. The telescope is mounted so that this axis is horizontal and exactly in the east-west direction. The telescope can therefore move only in the plane of the meridian. It is used for determining the times of transit of stars across the meridian. The transit instrument in conjunction with the mural quadrant determined two co-ordinates needed to fix the position of a star. It was invented by Roemer in 1689, and is still the standard instrument for determining the right ascensions of celestial bodies.

ZENITH SECTOR consisted of a telescope, pivoted at its upper end and capable of a small motion in the meridian on either side of the vertical, the position of the telescope being indicated by a small graduated sector at its lower end. It was used for observing stars where zenith distance is small, so that effects arising from uncertainties in atmospheric attraction would be avoided. It was designed with the intention of determining stellar distances, from the measurement of the small displacements of stars caused by the revolution of the earth round the sun.



A.—Small point, sharpened along two sides of a flake, used perhaps for gouging out wood or meat. *B.*—Small flake, somewhat thick, with opposing notches; this may have been used for scraping wooden sticks or simple bone tools. *C.*—Small flake trimmed on two sides to give a kind of 'nosed' working edge, for scraping or gouging.



D.—A larger flake showing preparation on a core before removal. One side has a sinuous knife edge. *E.*—A larger flake with one side finely retouched to produce a smooth sharp knife edge, perhaps for cutting.

F.—A pebble tool with a small flensing edge made by striking flakes alternately from either side. *G.*—A flake trimmed from one direction along several sides to produce a pointed tool.

EXAMPLES OF FLINT TOOLS FROM THE SHERINGHAM INDUSTRY.

c

g

The earliest 'man-made' industry known to science, found buried under the Ice Age boulder clays forming the cliffs at Sheringham, Norfolk, may shed light on the enigma of Man's origin. The data for this article were provided by Dr. Thomas T. Paterson, Director of Cambridge University's Museum of Archaeology, who carried out the research at Sheringham, and have been annotated by Douglas Liverside.

A Million-year-old 'Workshop'

Hidden beneath the bleak, craggy cliffs of Sheringham, Norfolk, may be the secret of the enigma scientists the world over are seeking: Man's origin. Discoveries last year suggested that Central Africa might be the cradle of the evolution of the ape family—including man—whose common ancestor science is striving to find.

But Dr. Thomas T. Paterson, Director of Cambridge University's Museum of Archaeology, contends that the tell-tale bones of the half-human, half-animal 'missing link' may lie under the Ice Age boulder clays that form Sheringham's cliffs, following his discovery of the earliest 'man-made' industry known to science. This anthropologist—who has studied Eskimo anthropology in Canadian Arctic territory and Greenland, excavated in northern India to trace prehistoric remains (the oldest in Asia) and mapped the glacial deposits of the Himalayas in Kashmir—has located flint workshops in which 'men' laboured at Sheringham at least 1,000,000 years ago.

For over forty years prehistorians in East Anglia have waged academic battle over pieces of flint, ostensibly struck off cobbles. These flakes—as they are known to prehistorians—are akin to the man-made flints of the Stone Age, which is confined to the later periods of the Great Ice Age (or Pleistocene).

But since these flakes were found in deposits of a more remote age, many scientists were loath to accept them as evidence of man's existence or even of a tool-making animal. For under certain circumstances similar flakes can be produced by natural processes.

Claimed certain scientists: "Battering on a beach would knock off flakes, and further battering would chip the edges as on man-made tools." So for years a wordy war ensued between those 'for' the human origin of the flakes and those 'against' it.

Dr. Paterson himself was an agnostic until lately when, during a holiday at Sheringham, he began a patient search for an old land surface, or the remains of one. He came across workshops in which 'man' laboured 1,000,000 years ago. Tools, manufactured by this early man of Norfolk, lay in profusion. One of five sites—about the size of a dining-table, 13 ft. by 2 ft. and 4 in. deep—yielded nearly 350 flakes in two days' digging. "It was a thrilling sensation," Dr. Paterson told me. "We gazed on the first working floor of pre-Ice Age Man and conclusive evidence of a tool-making animal. Here he came to stay or settle for some little time while he chipped himself some implements. Here he went into 'industry' about 250,000 years before the days of the South African Man—thought to be the earliest evidence of man's existence. The tools he used to hunt in the forests for food, to cut his meat and to sharpen wood."

These sites rest in a thin layer of pebbles, sand and clay on solid chalk, and are covered by 20 to 30 feet of reddish sands studded with marine shells. Over them lie stiff boulder clays and gravels—relics of the massive Ice Age glaciers.

It is a precarious task, this unravelling of the mysteries of this dark unknown. Over one site, for instance, lie 200 feet of these deposits; the biggest site is capped by about 100 feet, and to get at the stone bed in which the flakes lie, it was necessary to penetrate the cliffs from the shore.

Most of these flint tools are small—only a few exceeding one or two inches in length. One type of tool was obviously chipped from one direction to produce a razor-like edge. Maybe it was used for cutting up animals hunted in a sprawling plain where now stretches the North Sea, and for scraping meat off bones. Little notched scraping tools, chipped out of one side of a flake, were perhaps applied to stripping bark off wood and to shaping sticks. Occasionally there are two notches on opposite sides of a narrow flake. The part between, rounded off to form a 'nose-scraper' (as it is called), is ideal for hollowing out wood or for scraping out marrow bones.

Two types of tool predominate: one was fashioned by chipping two sides of the end of a small flake (like sharpening a pencil); another by cutting two notches close together, so that a point lies between. They may have been devised for boring holes in wood; perhaps the former was hafted to a wooden shaft as a weapon.

An infrequent tool is a wavy-edged pebble, produced by striking small flakes alternately from opposite directions along one edge. "This makes a good flensing knife," says Dr. Paterson, "for the edge throws up the skin which can be grasped more easily. I have seen Dr. L. S. B. Leakey in East Africa skin a buck with a stone knife faster than with steel, because of this advantage. Various larger tools were probably used as choppers—instruments for felling small trees or breaking bones."

How old are these tools? The very youngest saw the beginning of the Ice Age—nearly a million years ago. But some may be much older, for deposits—similar to that in which the Sheringham tools were located—also exist below marine sands of a period much earlier than the Ice Age.

These deposits were formed when the great Chalk formation of southern England—scoured smooth by the sea—was elevated, and a vast plain spread eastwards joining Britain to the Continent. The Rhine probably reached westwards to England; the Thames—with other eastern English rivers—flowed into it.

The climate was warmer than it is now. Many animals, now extinct, roamed this prehistoric wilderness, as, for instance, the ancestors of the elephant and the horse. It

is not impossible that man, or his ancestor, dwelt here in these dim ages of 1,500,000 years ago.

Slowly the land sank, submerged under a shallow sea. On the sea-bed sands with shells accumulated. Then the land rose again, the climate became less warm.

"And here," Dr. Paterson claims, "it is certain a tool-making animal or man roamed. That was a million years ago, when the English countryside was invaded by the earliest horse, elephant and wild cattle, and where deer, antelope, beaver, hyaena and leopard added a source of food—and terror."

Perhaps Britain's 'oldest inhabitants' hunted the smaller of these animals, for the teeth of the earliest Man known (and of his far-off ancestors) portray that he could eat flesh as well as vegetable foods. By comparing his tool types with those of modern primitive cultures—for instance the aboriginals of Australia and the extinct Tasmanians—one visualises him equipped with wooden spears, shaped straight and smooth with his notched scrapers. Possibly he made pointed sticks for digging roots, and cut them with his flint knife, also employed for stripping withies to make traps.

What form did this 'man' take? This, for the time being, must remain speculative. He was perhaps unclothed, had no home. Compared with the chimpanzee, the most advanced of the apes (it can spontaneously use sticks as tools; its other salient trick is the art of mime), it appears that Norfolk's early man was capable of visualising to himself his future course of action (for instance, in hunting); visualising the forms of weapons he would need; and also tools by which he could work them.

This is a stage of mental progress far beyond that of the chimpanzee, and not far different from that of the fossil Java Man (*Pithecanthropus*) and his near relative, the Pekin Man (*Sinanthropus*), both very primitive and of Middle Ice Age date.

Ancestral Man: Giant or Dwarf?

Actually, the tools linked with the Pekin Man are surprisingly like those unearthed in East Anglia. But they widely differ in size, being much bigger than the English. One may argue from this—and with some justification—that the creator of these tools was not so big as modern man.

"I believe," says Dr. Paterson, "he might have been built on the lines of the primitive pigmies of the African bush. The structure of his face was not unlike that of modern man, but with a receding chin. The small Australopithecines, lately discovered by Dr. Robert Broom in a South African lime quarry, have been described by Professor W. E. Le Gros Clark of Oxford University as small, ape-like in appearance, with an erect posture and a brain showing development implying good co-ordination of hand and eye, and conceptual faculties—attributes which would be needed by the tool-making animal of East Anglia."

These South African forms, according to the latest evidence, are of the early Ice Age; that is, about 250,000 years later than the Norfolk finds. But in that geological age a period of this nature was of no great consequence in man's evolution.

To suggest that the million-year-old ancestral man in England was small—like the Australopithecines—runs contrary to the opinion of American anthropologists who argue that humanity is descended from giants similar to the Java Man.

"I cannot conceive of such giant forms making tools like those we found at Sheringham," says Dr. Paterson. "In India, in 1935, in company with Dr. de Terra of Yale University, I discovered early Middle Ice Age tools of the kind associated with the Java Man. They are massive, some weighing up to seven pounds. And though prepared with fundamentally the same technique as those of East Anglia, they are so enormous that one must assume a tremendous difference in physique of the 'man' wielding them. It seems that we have some evidence in favour of the South African hypothesis of man's origin." If the Norfolk Man is traced, it may prove conclusively that man is derived from a small ape-like form and not a giant type.

England has abundant evidence of early human skeletal remains. About 100 years ago, near Ipswich (not far from Sheringham), a jaw-bone came from deposits of roughly the same age as the Sheringham 'industry'. It was described in a short paper to the Royal Anthropological Society, and a drawing exists. Moreover, it appeared to Thomas Huxley, the scientist who produced weighty evidence that man was descended from an ape-like ancestor, and to Falconer, the palaeontologist, to be definitely in the human category.

The bone was scorned, and eventually it reached America in the pocket of a Dr. R. H. Collyer, about 1880, after which it disappeared. The mystery has never been solved, unfortunately, for this is the oldest human fragment known to science. Its origin in bone-bearing deposits associated with stone tools excites great interest in America. At Harvard University plans have been mooted for sending an expedition to Britain to conduct large-scale excavations to trace man's immediate ancestry.

Certainly the chances of uncovering the 'missing link'—who made tools of the most primitive kind—are as good in England as anywhere in the world, if not more so. Conditions for preserving human remains are admirable, and with such a dense population the chance finding of fossil man is increased.

Already in England has been found the oldest true man-like fossil, the Piltdown Man, now on exhibition in the British Natural History Museum. He comes from the middle period of the Ice Age and is nearly 500,000 years old. A direct descendant, the Swanscombe Man, found in the Thames Valley, is an almost true modern type and about 300,000 years old. Of the same age is a skull, nearly complete, from Galley Hill, close to Swanscombe. This, in company with another Thames specimen from Baker's Hole, is about to be sold in the open market since the price sought is more than English museums can pay. Not even the British Museum can afford to buy them. It is a fair certainty that these two skulls will cross the Atlantic, where interest in man's origin appears to take a more concrete form than in Britain. To retain these scientific treasures in Britain, some anthropologists have attempted to invoke an old English law which demands the Christian reburial of excavated human remains. But unfortunately the time and place of burial is not specified.

The Galley Hill skull is so vital that an American anthropologist is travelling to Britain within the next few

[*Contd. on p. 113*

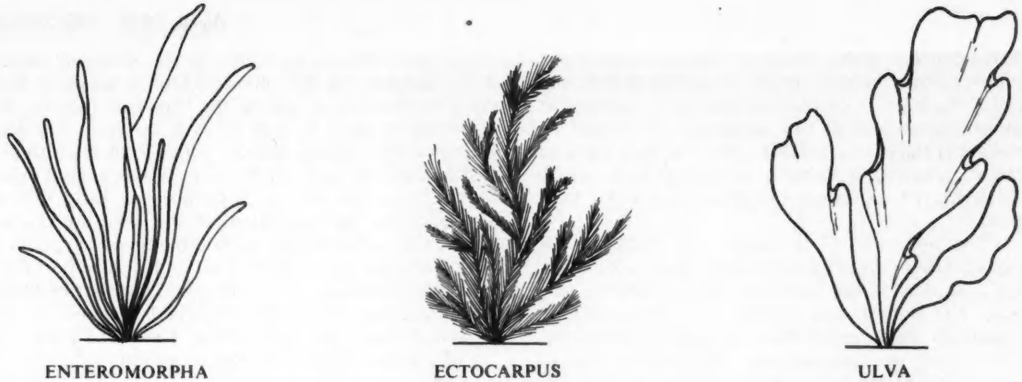


FIG. 1.—Outline sketches of three seaweeds that are found on ships' hulls. *Enteromorpha* (left), is the most common of the three forms shown, though *Ectocarpus* (centre) occurs often; *Ulva* (right), commonly known as sea lettuce, is much less frequent than the other two seaweeds.

The Problem of Ship Fouling

K. A. PYEFINCH, M.A.

THE settlement of marine algae and sedentary marine animals on the underwater parts of ships has probably provided a problem for their owners ever since ships became so large that they were able to be beached only at intervals. It still remains one of the ship-owner's problems today.

Though it is possible to quote a lengthy list of plant and animal species that have been recorded on ships' hulls, many of these either occur rarely or are only to be found on ships that are so heavily fouled that a complex marine community has become established on their hulls. The organisms commonly causing fouling are surprisingly few in number. A belt of seaweed fouling, sometimes narrow, sometimes extending several feet down the ship's side, commonly occurs at the water-line. This is largely composed of the green, grass-like threads of *Enteromorpha*, sometimes mixed with the branching filaments of the brown weed *Ectocarpus* or the flat fronds of the green 'sea lettuce', *Ulva* (Fig. 1). Animal fouling forms predominate over the rest of the hull. Of these acorn barnacles are the most common and important forms. Most of these acorn barnacles belong to the genus *Balanus*, and a number of the species of this genus are of common occurrence.* Calcareous tube-worms (often species of the genus *Hydroides*) almost rank with barnacles in importance (Fig. 5). Their sinuous, calcareous tubes, in contact with the substratum for practically the whole of their length, are particularly well adapted to resist forces tending to tear them away from the hull when the ship is in motion. Hydroids, such as *Obelia* and *Tubularia* (Fig. 4), are also frequently encountered in samples of fouling, but they are much less conspicuous than acorn barnacles or tube-worms and, as they are fragile enough to be broken away when the ship is in motion, their practical importance in reducing the speed of a ship is insignificant. It is impossible to describe here the host of sedentary marine animals which may occur on ships—mussels, oysters, encrusting and branching Polyzoa (sometimes termed 'coral' in the dockyard, though they are very different from the true corals), stalked or 'goose' barnacles, sea squirts and sea anemones—all are recorded from time to time, but perhaps enough has been said to sketch the outline of the community of marine organisms which may be found on the hull of a ship when she dry-docks after several months at sea.

Ships' speeds reduced

By increasing the frictional resistance to the passage of the ship through the water, the settlement and growth of fouling organisms reduces her speed or, if a given speed must be maintained, more fuel must be consumed to maintain it. Though this effect is universally recognised, it is difficult to obtain an estimate of its degree, as so many other factors may also affect the speed of a ship, for example differences in draft, varying qualities of fuel or bad weather. Losses of speed of the order of 2 knots (for a ship with a normal speed of 10-12 knots) can, however, be produced by fouling settlement. Translated into economic terms, this may make an important difference to the cost of transit of a cargo, quite apart from the expense involved in dry-docking and cleaning to remove the fouling.

The ship-owner, naturally enough, is primarily interested in the presence or absence of fouling. If his ships usually dry-dock in a fouled state, he is anxious to take any steps he can to eliminate or minimise settlement, but if fouling is absent, or is not usually severe, he is thankful to escape at least one source of worry and expense. To the biologist studying the fouling problem either condition is of interest, since each may suggest reasons for the success or failure of any measures taken to prevent fouling settlement.

* In temperate waters, *Balanus crenatus* and *B. improvisus* appear to be the most common forms, in tropical waters settlements of *B. amphitrite* and *B. tintinnabulum* occur most frequently. *Balanus balanoides* (Fig. 2), the common acorn barnacle which clothes rocks, piers and jetties between tide-marks, can also settle on surfaces which are continuously immersed. It is a common fouling form on vessels operating in the North Sea.

It is the purpose of this article to describe briefly some of the factors which seem to govern fouling settlement and to outline the kind of protective measures which are at present in use to prevent this settlement. It should be emphasised at the outset, however, that our knowledge of the factors affecting settlement, and particularly which factors are likely to operate at one place, is as yet far from complete.

It is first necessary to emphasise that settlement of fouling organisms takes place only when the ship is in port; fouling organisms do not become attached while the ship is at sea. This is partly because the settling stages of fouling organisms are often confined to inshore waters, but particularly because these settling stages cannot become attached to a substratum if the latter is moving at the speed of a ship in motion. In fact, recent work has suggested an even more severe limitation of the period available for settlement, since it has been shown that the larvae of some species of acorn barnacle cannot become attached if the water speed exceeds one knot. This indicates that, even when in port, the time available for settlement may be limited to periods when the tide is not running strongly, though this is perhaps offset to some extent by the fact that in many ports ships may berth in enclosed basins where the full effects of the tide may not be felt. Though direct experimental proof of this limitation of the period of settlement to slack water is at present only available for barnacle and tube-worm larvae, it would not be surprising to find it a factor applying to the settling stages of all fouling organisms.

The season of the year at which the port is visited is a factor of prime importance, particularly for ports in temperate waters. In tropical and sub-tropical waters settling stages may be available throughout the year, so that settlement may take place whenever the port is visited, but in temperate waters fouling is very definitely seasonal in its incidence and, though severe fouling can occur during visits to these ports during the 'summer' months, little settlement is likely at other times of the year. The actual length of this fouling 'season' varies from place to place in the temperate zone, but for most British ports it extends from early April to late September or early October. Though broad generalisations of this kind are useful as guides, they cannot always be strictly applied, as conditions, both from one site to another within the same port during one season and also at one site within one port in different seasons, can vary so considerably that it is almost necessary to consider each case on its merits. This is one of the points on which more detailed biological information is specially needed.

The length of stay in the port is the next factor to be considered. It is clear that the longer the stay, the greater are the chances of a large number of settling stages becoming attached to the hull, but length of stay is also important in less obvious ways. The settling stages of some fouling organisms (e.g. the larvae of some acorn barnacles, possibly the larvae of tube-worms) tend to be particularly abundant at intervals through the period during which they are available for settlement. A short stay may miss one of these periods of abundance; during a longer stay one is more likely to be encountered. Again, and this is probably a more important factor, a short stay does not allow such organisms as have become attached to become sufficiently established to withstand the more rigorous conditions which will prevail as soon as the ship puts to sea. The acorn barnacle, for example, probably cannot feed effectively when the ship is at sea since it uses its delicate thoracic appendages as a kind of net to trap small organisms in the water, and this is probably not possible in the current of water which must sweep over the surface of a

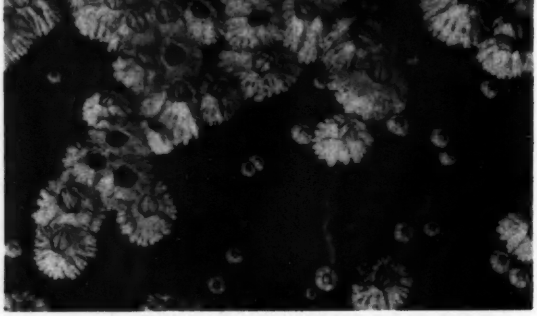


FIG. 2 (*left*).—The common acorn barnacle, *Balanus balanoides*, which covers rocks, piers and jetties between tide-marks, can also settle on surfaces that are continuously immersed. A common fouling form on vessels in the Irish Sea.

FIG. 3 (*right*).—The barnacle from Australasia, *Elminius modestus*, which is becoming a common shore form along the south and south-east coasts of England, and is appearing as a fouling organism on ships working out of ports along these coasts. A note about the nuisance it is causing to the British shell-fish industry is printed in this month's 'Progress of Science'.

ship in motion. If the barnacle has settled early in a long stay in one port, by the time the ship leaves it may have accumulated sufficient food reserves to enable it to withstand a period of starvation, but if the stay has been short, though settlement may have occurred effectively, the newly settled barnacle cannot survive the ensuing sea passage, dies and may be washed off.

The point just discussed also illustrates a further factor of importance—the length of the sea passage which follows a stay in port. If the time at sea is short, all, or practically all, the settlements at the previous port of call may survive, but recently settled forms may be lost if the time spent at sea is at all prolonged. This factor, the length of sea passage, is thus specially effective for recent settlements. If a fouling settlement has become well established, the constituent organisms show considerable powers of resistance to rigorous environments to which they are exposed. A recent case provides a good example. An inspection of a ship in dry dock in Liverpool showed the presence of the barnacle *Elminius modestus* (Fig. 3), a common estuarine barnacle in Australia and New Zealand, in the living state. As the ship inspected had sailed direct from the Antipodes to this country, via the Panama Canal, these barnacles had been able to survive a passage of about 30 days at a speed of some 17 knots.

FIG. 4.—*Tubularia*, a hydroid often found in samples of fouling. It is too fragile to be a serious ship-fouler.

The factors so far discussed are those which may be considered as general in their application. In addition, there are a number of factors which, more local in their application, are thus more variable in their incidence in any one voyage.

In some ports the salinity of the water is that of full sea water at all states of tide and times of the year, but in others the salinity may be markedly reduced at certain times, or the water may be entirely fresh. Few marine organisms can survive prolonged immersion in fresh water, so that a stay in a fresh-water port is likely to kill marine organisms that may have become attached at previous ports of call. If algal fouling, or the more delicate kinds of animal fouling (e.g. hydroids) are killed in this way, the dead individuals either drop off the hull or are easily washed away as soon as the ship moves. Organisms such as acorn barnacles, tube-worms and oysters, are not completely removed since, though their soft parts die and may be washed away, their shells remain, and the frictional resistance caused by their presence may not be much decreased.

In other ports the water may contain large amounts of sand and silt at certain times of the year, and this suspended matter, carried along by a rapid current, can exert a pronounced scouring action, removing not only the soft-bodied forms but also the shells and tubes of barnacles and tube-worms. A stay of a week or two in a port of this character can be sufficient to remove all previous fouling settlements. The effectiveness of such scouring ports is almost certainly increased by the fact that many are river ports (e.g. Matadi, on the Congo; the Yang-tze ports, etc.), so that the scouring effect of the suspended sand is reinforced by the lethal effect of the fresh water.

In a few ports the water contains enough industrial effluents to have a toxic effect, and visits to ports of this type may result in the removal of all previous settlements. An example of this effect is provided by the case of a vessel, recently inspected, which had had a period in service since her last dry-docking of about ten months. This period could be divided into two practically equal parts, separated by a stay of some six weeks in the Manchester Ship Canal. During both the early and the later parts of her voyage this vessel had been in ports where fouling settlement was likely and other conditions of both trips were such as to favour settlement and its persistence (e.g. length of stay in ports, no visits to fresh-water or scouring ports, etc.), yet all the fouling present had probably been acquired during the second half of the voyage. The period spent in the Manchester Ship Canal had presumably been sufficient to remove earlier settlements.

Up to this point no reference has been made to any methods of protection against fouling that are used. Though many devices have been suggested for eliminating fouling settlement, almost every ship-owner today attempts to solve this problem by applying an anti-fouling composition to the hull just before the ship leaves dry dock. Anti-fouling paints vary widely in their composition, but most of them contain poisonous compounds which are slowly released into the water as soon as the paint is immersed. Compounds of copper and mercury, particularly cuprous

and mercuric oxides, are frequently used as poisons. In a satisfactory anti-fouling composition, the poisons are released into the water at a rate which is just sufficient to prevent the settlement of fouling organisms but which is not so great as to waste the poison in the paint. As the amount of poison available for release over a given area depends upon the amount originally put in the paint and upon the weight of paint applied to this area and as the effectiveness of the paint depends upon the loss of this contained poison, it follows that an anti-fouling paint can only exert effective action for a limited period of time. After the rate of release of the poison has fallen so low as to be of little value, settlement of fouling on the paint surface becomes possible and the anti-fouling coating must be renewed. One serious cause of wastage of poison arises because the paint chemist must formulate his paint so that the rate of poison release is adequate in still water, where fouling settlement takes place. When the ship puts to sea, the rate of poison loss is considerably increased but, as fouling settlement is not possible when the ship is under way, this poison is wasted. Thus only a fraction of the poison originally introduced into the paint exerts its intended function. Therefore, although the application of an anti-fouling composition is the method almost universally used to prevent fouling settlement, it is by no means an ideal solution of the problem, and the production, for instance, of a coating from which poison could be released only when the ship was in port, would be an immense advance. The 'life' of such a composition would be considerably longer than that of the type of composition at present in use.

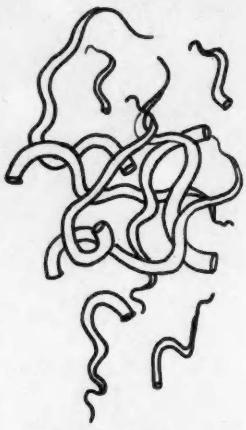


FIG. 5.—*Hyroides*, a genus of worms which build calcareous tubes, ranks close behind the barnacles as a ship-fouler.

The length of 'life' of anti-fouling compositions varies considerably, but, unless the composition used is a complete failure, there is a part of each voyage during which fouling settlement is prevented. Analyses of recent data suggest that this period usually does not exceed four months and is occasionally much shorter but it should be added that this deduction is based on observations made on anti-fouling compositions produced during the war when the poison content could not exceed a specified figure.

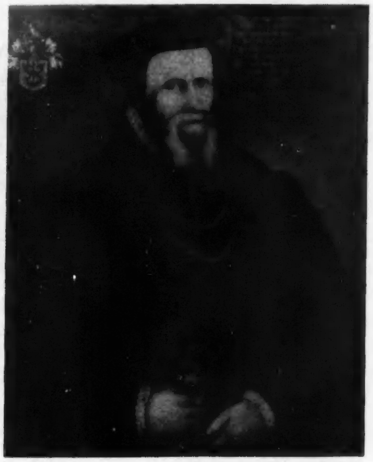
When a ship is examined in dry dock and samples of fouling are removed for identification, the biologist tries to reconstruct the sequence of fouling settlements that have occurred since the last dry-docking. It is not always possible to do this but sometimes, given a knowledge of the sequence of ports visited and the time spent in each, such a history can be tentatively reconstructed. This is made much easier if there are areas on the hull which have not received a coat of anti-fouling paint, since these should record the complete sequence of fouling settlements encountered. When tests are being made of experimental anti-fouling paints such 'non-toxic' areas are left deliberately, but in ordinary commercial practice this is, of course, not the case. Luckily it is the practice of some ship-owners to apply a special protective composition near the stern to protect the hull against corrosion which is liable to be particularly severe in the neighbourhood of the propellers. Such compositions possess excellent anti-corrosive properties, but rarely have any anti-fouling properties, and thus the areas to which they are applied serve as non-toxic control areas and the fouling settlements they bear are a most useful guide to the performance of the anti-fouling coating applied over the rest of the hull. A detailed study of the sequence of ports which a ship has visited and the time which she has spent in each can provide a valuable guide to the true performance of the anti-fouling composition applied at the last dry-docking. Anti-fouling compositions sometimes appear to be variable in their performance; after one voyage a vessel may return to dry-dock clean or only lightly fouled, after the next voyage she may be heavily fouled. The ship-owner is apt to draw the conclusion that the anti-fouling composition is unreliable but, while it cannot be claimed that such compositions are absolutely uniform in their performance, the considerations put forward in this article indicate that there may be reasons why a ship is not fouled after a particular voyage which have little connexion with the anti-fouling performance of the paint. A critical study of the ports visited may suggest some of these reasons and a slight variation in route may be possible which would appreciably reduce the chances of heavy fouling towards the end of her voyage.

(*Figs. 2–5 are from copyright photographs by Douglas P. Wilson.*)

THE DSIR'S most important single investigation in this field of operational research is into the problem of finding the most economical method of warming a house. The experiment is in two parts. In the first, eight houses have been built, identical in internal design but with different degrees of thermal insulation. The heating systems inside are of two types only so that the scientist can find out how much fuel is saved by the better insulation under actual living conditions. In the second part of the experiment, 20 houses with identical thermal insulation have been built; but in these houses the heating systems and appliances—92 are being tested—are different and the results will show which are the best and most economical. At first the houses are empty and conditions such as temperature, time of stoking, and ventilation are controlled. When comparable data on the effects of the different variables have been obtained in this way the houses are occupied by tenants and the experiments continued. The aim is to get a precise picture of the conditions in the houses as they are when actually lived in. The experiment is obviously very complex but the stake is very great, because 60 million tons of coal are used every year for domestic heating.—Sir Edward Appleton, addressing the F.B.I. meeting on March 18 in honour of the two 1947 Nobel Prize-winners.

Frontispiece of
Gerard's *Herball.*

John Parkinson
(1567–1650).



John Caius
(1510–1573).

(Continued from p. 90)

Evolution of British Natural History

R. P. HILL, B.Sc., A.R.C.S., D.I.C.

TURNER's contemporary John Caius was a man of a very different stamp. Born in Norwich in 1510, Caius came up to Gonville Hall, Cambridge, in 1529. He remained uninfluenced by the new religious ideas but was attracted towards a study of Greek, doing so well at it that he became a fellow of his college in 1533. In 1539 he turned his attention to medicine and, after studying under Montanus and Vesalius at Padua, gained his M.D. in 1541. He stayed on as lecturer on Aristotle in Greek for a further two years; then, after a tour of Italy, made his way home. In the course of this journey he met Gesner at Zurich and published a book *De Methodo Medendi* at Basle. There can be little doubt that Caius deliberately courted—and won—success in the field of medicine. He held himself aloof from all current controversy and professed belief in the infallibility of the ancient authorities.

His reward was the presidency of the College of Physicians on many occasions and the co-foundership of his old college at Cambridge. His master Vesalius, with whom Caius had lived during some part of the preparation of *De Fabrica Corporis Humani*, was inclined to be critical of Galen. It is typical of Caius that, as President of the College of Physicians in 1559, he ordered John Geynes, an M.D. of Oxford, to withdraw a statement imputing error to Galen on pain of being cast into gaol as a charlatan.

Caius's interest in natural history seems to have sprung from his friendship with Gesner. He made a considerable series of notes, chiefly in the field of zoology, many of which were incorporated by Gesner in his *Historia Animalium*, published in 1561. These notes show that Caius was an excellent observer and that he could draw uncommonly well—yet he was capable of stating that the animal known to the Norwegians as an Elk could not in fact be an Elk because the Norwegian beast had joints in its legs whereas the legs of the true Elk (cf. Caesar, *Gallic War*, Book vi, Ch. 27) have no joints. His collected biological work, including some material that had arrived too late for Gesner to use, was published in 1570 under the title *De Rariorum Animalium atque Stirpium Historia.* Caius was also the author of a famous study on dogs.

In the generation after Turner and Caius Cambridge produced yet another first-class naturalist. Thomas Penny graduated in 1551 and remained at the University studying divinity and medicine until 1565. In this year he was censured by Archbishop Parker as the result of a sermon and henceforward devoted his attention to medicine. There can be little doubt that by this time Penny had already come under the influence of William Turner. After the Archbishop's reprimand he set off for Zurich with an introduction to Gesner, doubtless obtained from Turner. He arrived some months before Gesner's untimely death in December 1565 and joined Jean Bauhin in working over the mass of botanical notes and pictures left by Gesner to Wolf. That Penny was deemed fit to collaborate with the great Bauhin in this work and that the notes he and Bauhin made were worthy of publication by Schmiedel some 200 years later is a measure of his stature as a botanist.

Between 1566 and 1569 Penny travelled a great deal in Europe and can claim two notable 'firsts': *Hypericum balearicum* (named Myrtocistus pennaei by de l'Ecluse) from Majorca, and the 'Chamaepericlymenum' (*Cornus suecica*) from the Baltic. At Montpellier in 1566 he met and became the friend of Mathias de l'Obel and, probably at Heidelberg, he made the acquaintance of Joachim Camerarius, author of *Hortus medicus,* who speaks of him with unusual warmth.

Penny returned to England with an M.D. in 1569 but was forbidden to practise by the College of Physicians. He was once gaoled for ignoring this ban but after that the matter seems to have been overlooked and Penny enjoyed a considerable reputation as a doctor. Probably in 1571 he made personal contact with the great Flemish botanist Charles de l'Ecluse.

Penny's Studies on Insects

As a botanist Penny seems to have been content to pass on his results to the great ones of his day; de l'Obel, de l'Ecluse and Camerarius the younger all acknowledge their indebtedness to him. The reason for this may have been Penny's growing interest in insects, in those days almost a virgin field. He accumulated a vast amount of material on the subject and there is no reason to believe that it was poorer in quality than his botanical work. Had Penny lived to arrange and publish it his name would have ranked with the greatest of his contemporaries and entomology would have received an incalculable impetus. Perhaps if he had left his papers to anyone but Thomas Mouffet there would have been a different story to tell. Penny died, a prematurely aged man, in 1588.

Mouffet, after a normal education for the time during which he gained the acquaintance of John Caius, became an M.D. of Cambridge in 1582. At this time he was working with Penny both in medicine and in natural history and it is probable that, under Penny's direction, he worked well and gained his master's respect. But he was a dilettante at heart. He seems to have put in a great deal of work on Penny's notes but his 'improvements' will not bear the test of examination. He rejected Penny's classification, substituting one of his own that could not very well have been worse. He cut out, as he claimed, over 'a thousand tautologies and trivialities' and in doing so robbed the work of much of its scientific value. He wrote a 'tinsel' Latin far less suited to the task in hand than Penny's dry, precise style. His additions to what remains of Penny's original notes are almost entirely lifted from Wotton, Gesner and Turner without acknowledgment. Lastly, least venial sin of all, he neglected the duty of publication so clearly laid upon him. The *Theatrum Insectorum* was finally printed in 1634, thirty years after Mouffet's death. Even so, when compared with the seven volumes of Ulisse Aldrovandi's *De Insectis*, its scientific merit is unmistakable. Penny's work is in fact the true foundation of entomology.

The radical changes which occurred during the latter half of the sixteenth century took time to percolate down to the level of the general culture. Evidence for this statement is Batman's attempt in 1582 to bring up to date Bartholomew's *De Proprietatibus* which had been a popular text-book in England for the last 300 years. Of greater service was Henry Lyte's *Niewe Herball*, a praiseworthy attempt to disseminate in England the new knowledge of botany that was accumulating on the Continent. Lyte's book was an English translation of de l'Ecluse's French version of Rembert Dodoens's *Cruydeboeck*.

A much better-known *Herball* was that of John Gerard, published in 1597. Gerard (1545–1607 was a rogue and a pirate. That he had some knowledge of botany is undeniable; he was a leading member of the Company of Barber-Surgeons, kept his own garden, and had published in 1596 a list of its contents with a commendatory note by de l'Obel. But he claims his *Herball* as his own work, whereas it is in fact a translation of Dodoens's *Pemptades* made by a certain Dr. Priest whose papers came into Gerard's possession. Gerard attempted to conceal what he had done by rearranging the classification to agree with that of de l'Obel but the work was so full of errors that the publisher called in de l'Obel himself to edit it. De l'Obel claims to have made more than a thousand corrections before Gerard lost his temper and insisted on publication.

What Lyte and Gerard had done for botany Edward Topsell attempted to do for zoology, following on Holland's translation into English of Pliny's *Natural History*—a work which supplanted Bartholomew as a text-book. Topsell in his two books (*Of Foure-footed Beastes*, 1607 and *Of Serpents*, 1608) gives Gesner's immense *Historia Animalium* as his authority. But his works are more than mere translations. In an age of plagiarism, he borrows extensively and without acknowledgment from Wotton and from the *Theatrum Insectorum* (he must have gained access to the notes in Mouffet's possession), even altering the locality of one of Penny's reports to make it look like his own. Zoology was at the time in a much more 'mediaeval' condition than botany, and Topsell's selection from the wide choice of beasts both real and fabled offered by Gesner shows that he knew no better. The only merit of his work is that it is in advance of any existing books on the subject in English. The study of zoology remained in this chaotic state until the time of Ray.

Parkinson and Johnson

But the botanists of this time were clearly out of the mediaeval rut and were beginning to make the approach advocated in more general terms by Francis Bacon. That England kept abreast of this movement is due almost entirely to de l'Obel whose presence in this country was a constant spur to the apothecaries. Of these early seventeenth-century apothecaries there are two who stand out from their fellows: John Parkinson and Thomas Johnson. Parkinson, who was known personally to de l'Obel, published in 1629 the first English gardening-book, *Paradisi in sole Paradisus terrestris*—'the park on earth of the park in sun'. In 1640 he brought out his *Theatrum Botanicum*, the largest of the British herbals and fit, according to Ray, to rank with the great continental histories of plants. It is obvious that the author has done his best to master the authorities and to present his facts honestly. If he owes much to de l'Obel he has the grace to admit his debt and does not really deserve the accusation of plagiarism levelled against him by How. The classification is based on pharmacology and therefore bears no relation to modern botanical classification but at least it is an advance on the alphabetical list of the previous century.

Thomas Johnson was a younger man than Parkinson and one of considerable ability. When it became known that Parkinson was about to produce a herbal the publishers of Gerard's *Herball* asked Johnson to undertake a major revision of Gerard's work in an endeavour to forestall him. It is scarcely to Johnson's credit that he

Frontispiece of Mouffet's *Theatrum Insectorum*, bearing medallion pictures of Gesner, Wotton, Penny and Mouffet. (*By permission of the Trustees of the British Museum.*)

accepted the task so eagerly but it must be admitted that he made an excellent job of it; he clearly had no illusions about Gerard and dealt with him without mercy. Yet perhaps the most valuable part of Johnson's work lies not in his corrections and improvements of Gerard but in his own additions to the original material. There is in particular an admirable history of botany which shows that he was well acquainted with the literature of his subject. His style is more lucid than Parkinson's and, had he not been led to concentrate on the revision of Gerard, it is possible that he might have produced a better herbal than the *Theatrum Botanicum*. There is evidence that Johnson and his associates were planning a first complete British Flora, a work of which we were deprived by Johnson's untimely death in 1644 while fighting in the Royalist cause.

Johnson's death might have been a more serious blow to botany but for the existence of his *Mercurius*, an extensive account of his botanising expeditions in Britain. This formed the basis of William How's *Phytologia Britannica* published in 1650. How's work, incomplete and defective though it is, brings to light the number of amateur naturalists who, throughout the country, were collecting, describing and identifying plants. The *Phytologia* was something of a best-seller—another indication of the enthusiasm for botany then prevalent in the country. Due probably to this intense botanical activity, interest now began to grow in other branches of natural history, and there was a demand for a larger and more comprehensive work. How died before he could take any steps to meet it, and the task fell to Christopher Merret whose *Pinax Rerum Naturalium Britannicarum*, published in 1666, covered the flora, fauna, fossils and minerals of Britain. Merret was no botanist. He employed a paid collector and relied to a still greater extent upon contributions sent in by amateurs, a few of which may have come from Ray. Ray's description of Merret's handling of the botanical section is 'bungling'. The section on the fauna is based mainly on Johnstone, Gesner and Aldrovandi. Turner on birds is used, via Gesner, and Turner's famous letter to Gesner supplies most of the fish listed. The information on insects comes partly from Mouffet and partly from Aldrovandi, but there is an interesting attempt to classify the quadrupeds which seems to be Merret's own. On the subject of fossils Merret states his belief that they "are fashioned out of animals or their parts through the action of some earthen fluid" after which the organic matter rots leaving only the impression on the rock. This is worth recording since Nils Stenson's *De Solido intra Solidum contento* was not published until 1669.

The year 1662 saw the foundation of the Royal Society. Merret had been one of its original members but his name is lost among the list of the great ones who were associated with its early years. John Wilkins, William Petty, Christopher Wren, Robert Boyle, John Ray, Isaac Barrow, Nehemiah Grew, Isaac Newton, Robert Hooke, Edmund Halley, John Flamsteed, John Evelyn, Samuel Pepys . . . "there has," comments Professor Raven, "seldom been in all history—never been in our own—so remarkable a group". Under their guidance, science as we know it today came into being.

With John Ray the final step in the evolution of natural history was taken. The natural history of Neckam and Bartholomew reflected the spirit of the Middle Ages wherein "the achievements of Greek and of Classical Roman civilisation had . . . been transmuted into a traditional lore in which a recognisable nucleus of original authority could scarcely be disinterred from the mass of glosses, accretions, syncretisms and moralisings which pious imagination and fear had imposed upon it". The natural history of Wotton and Turner reflects the spirit of the Renaissance which, having rediscovered the 'original authority', failed to recapture the spirit of the ancients through excessive admiration for their works. The natural history of Ray reflects the modern spirit, the sceptical spirit, the spirit of Aristotle.

(The portrait of Caius is from a picture in Gonville and Caius College, by permission of the Master and Fellows, and also Cambridge University Press.)

JUNIOR SCIENCE

How the Ear Works—I

After the eye, the ear is the next important sense organ. Actually, in some ways it is more important than the eye: a blind person can lead a tolerable life with suitable training, but a deaf person is much more cut off from other people.

Another reason for the importance of the ear is that, quite apart from enabling us to hear, it helps us to keep our balance. I shall come to that next month.

If you play a note on the piano one of the wire 'strings' is made to vibrate rapidly. This causes movements of the air: you can't see them, but you can imagine them as rather like the ripples produced when you drop a stone in a pond. We hear the piano note, or any other sound, because the ripples in the air cause movements in various parts of our ear.

If you look at Fig. 1 you will see that there is a lot more to the ear than the flap of skin and gristle on the side of the head: that is only the *external ear*. When sound-waves in the air enter the ear hole (which is also part of the external ear), they come to the ear drum, and make it vibrate. The ear drum is attached to a set of very small bones; these small bones are in a space in the bone of the skull, and this space and its contents are known as the *middle ear*.

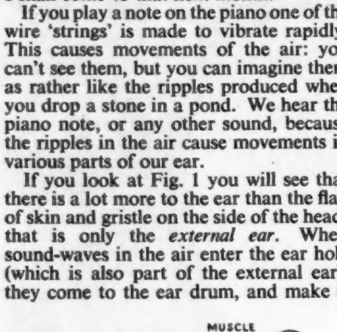


Fig. 1.—The ear as you would see it if you cut through the bone to expose the inner cavities.

You will see that the middle ear is connected by a narrow tube to the throat. That tube is especially important for people who travel by air. The reason is this. In the ordinary way the pressure of the air on each side of the ear drum is the same: that is, the pressure in the middle ear equals the pressure outside, and so the drum is quite flat. But if you climb several thousand feet quickly in an aircraft you get to air which is at a noticeably lower pressure than at ground level; there is then less pressure on the outside of the ear drum, and the drum bulges outwards. When this happens an experienced flier makes swallowing movements which open the tube from the middle ear to the throat, and so he equalises the pressure on the two sides. On a rapid dive this is even more necessary, but in this instance the pressure outside is higher, and the drum bulges inwards. The same thing is liable to happen when a tube train carries you quickly underground, because the train, travelling at speed in a narrow tunnel, causes a local increase in pressure.

When the ear drum vibrates on the arrival of sound waves the middle ear bones also vibrate, and so transmit the vibration to another membrane which lies between the middle ear and the *inner ear*. The inner ear is a complex system of channels in bone. The channels, which are shown in the diagram, are lined with cells, many of them especially sensitive; and they contain a watery fluid.

The part concerned with hearing is the cochlea—a coiled tube narrow at one end and broadening out towards the other. It is rather like a snail shell in shape. The whole of it, however, is so small that its structure has to be studied with a microscope. If you cut a thin slice across the cochlea at one point in the coil and look at it under a microscope you see the structures shown in Fig. 2. The spaces are three channels containing fluid. When sound waves reach the inner ear they are transmitted through this fluid, and they cause the *basilar membrane* to vibrate. This movement causes the sensitive cells attached to it to move as well. The sensitive cells have fine projections attached to a membrane above, and the movement pulls on these projections. The sensitive cells (like the sense organs of the skin, and of the retina of the eye, that I have already described) are connected to nerve fibres. And when the sensitive cells are pulled, the nerve fibres transmit messages to the brain.

Next month I will say more about how the inner ear works. Anthony Barnett

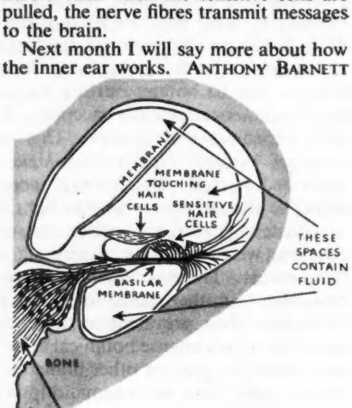


Fig. 2.—What you see if you cut a thin slice across the cochlea (for example, where line A has been drawn across it in the other diagram).

Far and Near

A New Nitrogenous Fertiliser

During the past twelve months the U.S. Department of Agriculture have been developing an entirely new fertiliser, based upon a resinous material formed when urea and formaldehyde are boiled together at reduced pressure. The resinous slurry formed is washed free from acid and dried. The fertiliser has been given the name 'Urea-Form' though some American references already shorten this to 'Uraform'.

The great importance of this fertiliser is that it is the first insoluble nitrogenous fertiliser of the chemical or non-organic-origin class. It possesses the traditional advantage of materials like hoof and horn or dried blood inasmuch as it is only slowly converted into soluble nitrogen compounds in the soil, thus supplying nitrogen steadily over a long period. The more readily soluble and quickly nitrified fertilisers have always provided most of their nutritional value in one short and intensive burst of activity, and often there is considerable loss of excess nitrate through leaching.

'Urea-Form' contains about 37% nitrogen, so that it is about three times as concentrated as the best of the organic fertilisers. Also, unlike other concentrated nitrogenous materials, it can absorb water substantially without caking or setting, which is another outstanding advantage. It remains to be seen whether this new fertiliser can be produced in quantity at a reasonably competitive price; though even at a fairly high price it should find a ready demand in the horticultural field where organics are at present used so intensively.

A New Dyestuff: Alcian Blue

In 1935 Monastral Blue, belonging to an entirely new class of synthetic pigments, was first prepared on a large scale by Imperial Chemical Industries, after several years of development following the initial discovery of the pigment about twenty years ago. Monastral Blue could not be used for dyeing textiles, being insoluble, so the search began for a method whereby it could be rendered temporarily soluble. The result of this research in the laboratories of I.C.I.'s Dyestuff Division at Blackley is the dyestuff Alcian Blue. Eminently suitable for printing textiles, particularly cotton, it gives bright turquoise shades hitherto unobtainable. Alcian Blue may be printed on linen, viscose, spun viscose and cuprammonium rayons, acetate rayon, natural silk, chlorinated wool, nylon and paper. Of particular interest is the fact that the shade remains practically constant on these different materials.

B.I.O.S. Summaries to be Published

Readers are by this time familiar with the activities in Germany of B.I.O.S. (British Intelligence Objectives Sub-Committee), its American counterpart, F.I.A.T. (Field Information Agency, Technical), and

the combined Anglo-American Agency, C.I.O.S. (Combined Intelligence Objectives Sub-Committee) which preceded them.

Actual investigations in Germany ceased at the end of June 1947. To date 2774 reports have been issued covering the investigations in which more than 6000 investigators took part, and the task of preparing these reports on different aspects of each industry is rapidly being completed. These reports may be consulted at the principal public libraries, chambers of commerce, universities and scientific institutions. Copies may be purchased from H.M. Stationery Office (by post through P.O. Box, 569, London, S.E.1). Canadian subscribers should apply to the Liaison Office, National Research Council, Ottawa. Enquiries about original German documents, drawings, etc., mentioned in these publications should be addressed to *T.I.D.U., German Division, Board of Trade, 40, Cadogan Square, London, S.W.1* quoting references by report and page number.

Reports summarising the facts collected by the various missions are being prepared under the editorship of K.O. Michaelis, and these are being published under the general name of B.I.O.S. Overall Reports. There will be fifty in all. In compiling these summaries all available information about German techniques has been sifted and critically compared with the latest British practices. The first six 'Overall Reports' deal respectively with petroleum and synthetic oil; shipbuilding and marine engineering; the timber industry; the glass industry; the German road system; some aspects of German agriculture during the war; the rubber industry.

The Most Promising Radium Substitute

MOST promising of the radioactive substances produced in the atomic pile from the point of view of being a possible substitute for radium is the isotope of cobalt, Co 60. This opinion was expressed by Prof. W. V. Mayneord of the Cancer Free Hospital, Fulham, in a recent lecture to the Linnean Society in which he described some applications of nuclear physics in biology and medicine.

Cobalt 60 is prepared by bombarding ordinary cobalt (Co 59) with neutrons in the atomic pile. Beta and gamma rays are emitted in the radioactive decay of Cobalt 60.

New Developments in Electron Microscopy

LAST autumn the Institute of Physics organised a conference at which new technical developments in the field of electron microscopy were discussed. The conference proceedings have just been published and are available from the Institute (47, Belgrave Square, London, S.W.1), price 2*s*. 6*d*. post free. New instruments described include the French (C.S.F.) Self-emission Microscope and the E.M.3 Electron Microscope made by Metropolitan-Vickers. Techniques of mounting objects and preparing replicas for examination with the electron microscope are also dealt with, while other papers describe some of the structural details of bacteria, viruses, cancer tissue and muscle which the microscope has revealed. Worthy of special mention are the papers of Dr. V. E. Coslett on the deterioration of specimens in the electron beam, and of Dr. R. Reed and A. Millard on the choice of photographic media for taking electron micrographs.

Radiophosphorus upsets Chromosomes

IN a note to the American journal *Science* (Feb. 20, 1948), T. N. Arnason, Elaine Cumming and J. W. T. Spinks report an experiment in which radiophosphorus (P32) was administered to germinating wheat and barley seeds. Subsequent examination of the cells of the flowers showed differences in chromosome structure, including actual breakages of the chromosomes, from normal untreated plants. The authors consider that the radiations emanating from the radiophosphorus are the cause of these changes (by analogy with X-rays), and point out the probability of the radio-element having been actually incorporated into the chemical structure of the chromosomes.

Aeronautical Engineering Scholarship for Girls

THE foundation of a new aeronautical engineering scholarship for women is announced. Its total value is £200. Candidates, who must be no older than 20 and no younger than 15 on September 1, 1947, should obtain application forms from the Women's Engineering Society, 35, Grosvenor Place, S.W.1. Applications must be received by April 30.

Army Scientific Adviser

THE War Office announces that Professor F. J. M. Stratton is accepting a temporary appointment as deputy to the Scientific Adviser to the Army Council. Professor Stratton lately retired from the Professorship of Astrophysics at Cambridge University.

Timber Decay and its Prevention

THE loss of timber through decay is estimated at about 10% of the timber cut. The present scarcity of wood, and the fact that a very large proportion has to be imported, makes the prevention of decay of special importance. There are few modern text-books which deal comprehensively with the problem of timber decay and its prevention, but the gap is filled by a book, *Decay of Timber and its Prevention*, which covers the whole field exhaustively, published for the Department of Scientific and Industrial Research by H.M. Stationery Office, price 12*s*. 6*d*. This book, compiled by Mr. K. St. G. Cartwright and Dr. W. P. K. Findlay, of the Forest Products Research Laboratory, will be of lasting value to users of wood generally.

Considerable attention is paid to dry-rot, a problem which first engaged the attention of architects and builders at the beginning of the last century, and became increasingly serious as softwoods replaced oak for building purposes. A conservative estimate made in 1939 of the cost of repairing damage by dry-rot showed that it could not be less than £1,000,000 annually. Owing to bomb damage and the neglect of property during the war, this figure must now be considerably exceeded. Even in a small house the cost of repairs may amount to several hundred pounds. In addition to detailing methods of prevention and treatment, the book describes how householders and prospective purchasers can recognise the presence of dry-rot before floors are opened up or woodwork taken down.

Eleven 'Exceptional' Government Scientists

BEFORE the publication of the White Paper on the Scientific Civil Service (Cmd. 6679) in 1945, the higher salaries went with appointments carrying heavy administrative responsibilities, which meant that there was little encouragement for exceptional research workers who as a general rule had to decide whether they wanted advancement in the civil service sense even if this meant a diversion from original research because of administrative duties, or whether they would concentrate on research though this might involve considerable financial sacrifice. Now special posts have been created so that research workers of exceptional talent can be promoted to the Senior Principal Scientific Officer grade, for which the salary scale is £1320–£1520, and yet remain free of administrative duties. Last year fourteen scientists were promoted under this scheme, and it was then stated that the Treasury would be prepared to authorise in all about forty such promotions.

Another eleven have just been announced. The scientists concerned are:

H. BARRELL (National Physical Laboratory), W. BINKS (National Physical Laboratory), H. CARMICHAEL (Ministry of Supply), Dr. C. M. CAWLEY, I. FAGELSTON (Admiralty), J. L. HARDY (Ministry of Supply), A. W. HOTHERSALL (Ministry of Supply), B. PONTECORVO (Ministry of Supply), DR. R. H. PURCELL (Admiralty), H. A. SLOMAN (National Physical Laboratory) and A. G. TARRANT (Road Research Station, D.S.I.R.).

Geological Congress in Britain

SOME 1100 overseas geologists are expected to attend the 18th session of the International Geological Congress to be held in Britain in the late summer. The total attendance, including British geologists, is likely to approach 2000.

The Congress will hold most of its meetings at the Royal Geographical Society and the Imperial College of Science and Technology. Nearly forty geological excursions have been arranged and these are planned on an ambitious scale. One, foi instance, will demonstrate the general geology of Scotland.

Full details can be obtained from: The General Secretaries, 18th Session International Geological Congress, Geological Survey and Museum, Exhibition Road, London, S.W.7.

Correction

IT is regretted that in the last Junior Science note (Vol. ix, 3, p. 98) the terms aqueous humor and vitreous humor were inadvertently interchanged both in the illustration and in paragraph two of the text.

Letters to the Editor

SIR—In your issue for February 1948 I have been reading Mr. Raymond Glascock's most interesting article on 'Labelled Atoms'.

On page 59 the author says "... and as the plant could not distinguish between radioactive and inactive lead the value thus obtained was the fraction of the total lead absorbed by the organ." I would like to ask Mr. Glascock whether the plant's ignorance is a well-established scientific fact—or assumed for the purpose of the interpretation of the results of the experiment.

After all when one considers the chemical synthesis and analysis which a plant achieves in its cellular laboratories at N.T.P. and without apparatus—operations many of which we cannot begin to emulate for all our equipment—it would appear to the lay mind that isotopic discrimination—particularly when a radioactive isotope is involved—would not be beyond its capacity. In fact one would have expected that the plant in question would have known whether it was being fed on Thorium B as well as normal lead. Whether the plant may or may not have acted on this knowledge in such a way as to cause false conclusions to be drawn is beside the question.

I understand that fishes realise only too well when the proportion of 'heavy' hydrogen to ordinary hydrogen in water is too high—and register their appreciation of this fact by dying.

Yours etc., HENRY M. A. CECIL.
Cmdr. R.N. (Rtd.)

We referred this letter to the author, and this is his reply:

As Commander Cecil implies, it is unwise to assume ignorance in anything—even a plant; in this case, however, there are good grounds for supposing that living organisms cannot distinguish between isotopes.

Apart from the theoretical considerations (chemical changes are concerned only with the outside of the atom and not the nucleus) and the hundreds of recent tracer experiments which lead to conclusions in accord with those deduced from other work, there are also several on record in which concordant results are given by tracing the same substance labelled first with one isotope and then with another. Short-lived radio-carbon (C^{14}) and long-lived radio-carbon (C^{11}) have both yielded similar results when used to label carbon dioxide in photosynthesis experiments. Yet the first is one mass unit *lighter* and the other two mass units *heavier* than the common isotope (C^{12}). If discrimination between isotopes occurred we would hardly expect it to be in the same way for both.

Furthermore, if plants and animals were capable of distinguishing between isotopes we would expect the naturally occurring isotopes of an element such as carbon or nitrogen to differ markedly in relative abundance according to the source. That is to say, if plants used one isotope preferentially, a lower concentration than normal of the other isotope would be found in plant tissues. But this is not so.

It is not necessary for me to add, surely, that radioactive substances do not form a special case. Until the instant of disintegration an unstable atom is 'just another atom' and does not differ, up to that moment, in anything but mass from the stable atoms of the same species.

As for the isotopes of hydrogen, it may be true that some fish are not as ignorant as might be expected from their appearance. Deuterium is, as I stated in the first part of the article, an extreme case as the heavy isotope is *twice* the mass of the lighter. Some very sensitive mechanisms such as those involved in enzyme action (on which, for example, respiration depends) are put out of action if the medium contains more than about 6% of the heavy isotope.
R. GLASCOCK.

SIR—Your article on Operational Research (DISCOVERY, January 1948) will be of interest to all social scientists for two reasons:

(1) It makes clear the fact that the "operational research worker can never consider technical improvements in isolation—they must always be related to organisational and human practice".

(2) Despite this the author of the article says, "Social scientists are not equipped to introduce measurements into social problems" and the article indicates that leading natural scientists who happen to have worked in the operational research field are of the opinion that "it was only the physical scientist who could encourage numerical thinking on operation matters".

The second conclusion will come as a surprise to those social scientists who have spent the whole of their working lives in empirical social research and whose work has been inspired by the brilliant efforts of Sir Cyril Burt, Charles Booth and the early English social surveyors, or the British demographers; social psychologists like the American Rensis Likert; or Professor Mahalonobis and his Indian Statistical Institute. It will also surprise those social scientists whose war-time work laid the foundations for the successful planning on the home domestic front which provided the base for the successful military operations enumerated in the article.

It is surely agreed on all sides that what is required now is a joint effort of multi-disciplined teams of scientists. Men trained in either the social or physical sciences who are capable of working with other scientists, whose training is different from their own, on problems in which both have an interest and to which both have a substantial contribution to make. So long as there are physical scientists who profess to believe that they alone know how the scientific method can be applied so long will social scientists be dubious about the possibilities of effective co-operation in such joint teams. On the other hand social scientists whose training and work in empirical methods enables them to make contributions to the solution of these national problems will have no hesitation whatsoever in working alongside natural scientists if the outmoded conceptions of the superiority of the natural sciences revealed in the article disappear.
LOUIS MOSS.

The Bookshelf

One, Two, Three . . . Infinity. By George Gamow. (Macmillan, London, 1947; pp. 340, 8 plates, 128 illustrations, 24*s*.)

PROFESSOR GAMOW presents, in a popular form, a collection of some of the most interesting facts and theories of modern science; there are four main headings—numbers, space and time, atoms and life, and the origin of the universe. He tells us that he originally set out to write this book for children, but decided at the end that it was not, after all, suitable for them. It follows that the presentation is uneven. The whole will, however, be of interest to those who are trying to follow the trend of modern science in these fields with only very limited scientific training.

There are many topics that are well handled in the author's characteristically chatty style. Among these, mathematical theorems on infinities and topological studies are not often found treated in a popular manner. The atomic theory chapter is clearly set out, particularly in its references to the neutrino and the intercombinations between the elementary particles. Probabilities lend themselves well to the author's style, and he leads us gently through Brownian motion, thermal agitation and diffusion to a statistical treatment of the Second Law of Thermodynamics. Genes and chromosomes are dealt with in a simple and direct chapter which includes an exciting diversion in the form of the hypothetical reaction:

$$3H_2O + 2CO_2 + (C_2H_5OH) \rightarrow 2(C_2H_5OH) + 3O_2$$

by which the auto-synthesis of alcohol is accomplished by the addition of a drop of whisky to a glass of soda-water!

But there is always present the danger that the creator of Mr. Thompkins may draw an analogy so broadly that it obscures the point to be illustrated. Considerations of imaginary numbers, four dimensions and relativity suffer most in this respect.

While the book contains much that will interest and amuse it also contains a great deal that will irritate. The profuse line drawings by the author tend to vulgarise rather than to popularise the subject. His sketches of several famous scientists are not good enough to be likenesses and not funny enough to be caricatures: they are frankly in bad taste. So, too, are such things as the sketch of the aircraft hitting the Empire State Building, and the symbolic representation of scientific observers throughout by detached eye-balls. Professor Gamow would be wise to leave his future illustrations to full-time artists.
S. J. B.

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